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GIST
OF EVOLUTION

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THE GIST OF EVOLUTION

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THE
GIST OF EVOLUTION

BY

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PREFACE

Since his participation in the Scopes trial the writer has been the recipient of many letters from persons in nearly every walk of life, asking for copies of his statement, expressing approval of his ideas, propounding specific questions, and requesting names of books on the subject that could be understood by those unversed in biology. Several have said that the books suggested were too long and involved or too technical for popular reading, while the avowedly popular statements were too wordy and lacked authenticity.

Why would it not be possible for a specialist in the subject of evolutionary biology to write a brief and clear statement for popular use, avoiding technical language as far as possible? The present volume is the result of a conviction that there is a real demand for a popular statement by a specialist and that such a statement will meet with public approval. If the reader desires a more comprehensive discussion of the various problems involved, he will find useful the writer's volume, *Evolution, Genetics and Eugenics.* (University of Chicago Press.)

H. H. Newman.

Chicago, Sept. 12, 1925.

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THE GIST OF EVOLUTION

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THE GIST OF EVOLUTION

CHAPTER I

INTRODUCTION

Fear of Evolution Due to Misunderstanding

It is our conviction, after a close study of the history of the present campaign on the part of those who desire to suppress the teaching of evolution, that the whole complex of fear and hatred of this idea has its roots in ignorance of the true meaning of evolution and in a misunderstanding of its relation to science in general, to philosophy, to civilization, and to religion.

The attitude of the anti-evolutionists is that evolution is essentially an irreligious, even a wicked idea —an idea so ungodly that they not only refuse to inform themselves about it, but are determined that their children and neighbors shall not be contaminated by it. They have closed their minds to it as is evidenced by the fact that they refuse to give the advocates of evolution an opportunity to show the reasonableness of their views. At the recent Dayton trial the expert witnesses, who were prepared to explain what evolution is and to indicate the evidences for its validity, were summarily refused an opportunity to inform the public about this most interesting of scientific generalizations. Both the prosecuting attorneys and the judge, after hearing a meager sample of the type of evidence an evolutionist had to offer, decided that it would be dangerous not only for the people of Tennessee but for those of the civilized world in general to learn any more about the subject. Evidently they felt that there was grave danger that an intelligent people, once hearing an adequate statement of the facts, would be in danger of accepting them and thus fall into line with the great army of those who have opened their minds to truth.

This fear of evolution involves also a fear of science in general. Fundamentalists hold that people should be kept in ignorance of all that man has learned about nature, for the facts of nature constitute a denial of some of the most cherished doctrines of their religion, doctrines that crystallized during the middle ages and have become grounded in the minds and hearts of generations of theologians and their adherents.

Without attempting the task of discussing the validity of any religious doctrines, it may at least be said that truth about nature has a higher validity than any doctrine, and that where there is an actual, not a fancied, conflict between demonstrated fact and any of man's doctrines, the intellect should be the judge between them. I firmly believe that the true spirit of religion and the realities of science are not only compatible; they are two aspects of the one great reality.

If this is truly the case—and it is part of our purpose to prove it—there is no foundation for the fear of evolution. Rightly understood, evolution lends new values and a new content to religion. It not only does not deny the existence of a supreme being; it actually tends strongly to support the belief in God and to open our eyes to some of the marvels of His methods.

The Campaign of Education. Feeling as we do that evolution is not only a valuable ally to religion but by far the most fruitful working hypothesis that science possesses, it behooves some of us who have made the study of this great principle a life work to do what we can to impart to the public the reasons for our faith. It is not an easy matter to explain in brief space and in lucid language free from technicalities what we know and what we think about this difficult and extremely complex conception. Even those of us who are specialists in the field of evolutionary biology find ourselves at times overwhelmed with a feeling of the immensity of the whole thing and grow discouraged at our lack of understanding of many of its phenomena. No doubt the physicist has a kindred feeling when confronted by some of his unsolved problems. The chemist, the astronomer, the geologist, equally with the biologist and the physicist, feel the inadequacy of their present knowledge of their subjects. There is no science today whose problems are definitely and finally solved. Yet all sciences are making progress. Every year new light is shed upon old problems. Little by little we approach an adequate understanding of many of the workings of nature that formerly were looked upon as unfathomable mysteries. Today we do not look upon scientific laws, principles, theories, hypotheses, as final. Our experience is that with a steady increase in knowledge our laws gain new content, our principles grow and broaden with increased understanding of facts, our theories shift a little and take on new meaning with each new discovery, and our working hypotheses are either confirmed or abandoned according to whether they continue to work or fail to agree with new knowledge. There is no finality about scientific generalizations. Yet, because we cannot state the final explanation of natural phenomena, should we keep secret what is known or should we share with the public what we do know and what we surmise to be true, frankly admitting that we do not know all that is to be known?

Evolution is a science in itself. It consists of a complex body of facts and theories. Many theories are so well-grounded in fact that they seem impregnable, others are at present mere tentative attempts at explanation, while still others bid fair to gain a permanent footing though as yet lacking the clearness and completeness that a mature theory should have. Though some of our theories as to causes and processes actually do fail to give entire satisfaction, there is much that we feel sure about and that the public is entitled to know.

The time has come when students of evolution must take the reading public into their confidence. Be it known that we realize that the statements we make today may need modification tomorrow if some radically new discovery should require such modification. All that we claim to be able to give the public is what seems to us as students of the subject to be the best possible statement in view of the facts at present known. The public has a right to know the pros and cons of each theory, to know what interpretation or interpretations may be placed upon known facts. In short, the public should be informed as to the true inwardness of evolution and all it implies. It is with confidence then that we offer the present statement—a confidence that candor and good faith will be appreciated and will gain for our principle more supporters than would a pretense of omniscience and certitude. We wish the public to see evolution as it is, to see its weak points as well as its general strength, to realize that it is a young and growing science that has not as yet reached its full stature nor attained the nicety of balance that comes with age and maturity.

The Age-old Conflict Between Science and Theology

The attempt to suppress by force the teaching of science is no new thing. Nothing is clearer to the student of history than the fact that every new and striking scientific discovery of major importance has been the object of bitter opposition on the part of the dominant religious organizations of the day. When the first theories as to the sphericity of the earth were published abroad they were denounced as opposed to the scriptures and therefore irreligious, for the Bible describes the earth as a flat body with four corners, covered over with a solid firmament inlaid with stars. Gradually, however, even the most dogmatic of theologians came to be convinced of the earth's sphericity, till now only Voliva and a few others of his ilk still believe in a flat earth. When the Copernican Theory of the solar system, involving the idea of a central sun with the earth and other planets circling in orbits around it, was announced, Copernicus and his followers were assailed by the leaders of the church as heretics and in some cases put to torture to compel them to recant their views. Martin Luther called the Copernican Theory "the work of a fool." John Wesley declared that it tended toward infidelity. Newton's Theory of Gravity met with a similar hostile reception and was attacked on the ground that it was atheistic, since "it drove God out of His universe and put a law in His place." Still more recently the attack shifted to historical Geology with its view that the earth has had an age-long history of development, that continents have been elevated, have been eroded down to a condition nearly level, that mountains have been formed only to wear away and disappear; in brief, that the face of the earth is undergoing and has undergone vast changes. Because the Bible holds many references to the fixity and unchangeability of the earth, of the mountains, of the seas, it was thought irreligious to speak of them as undergoing change. Christian geologists even of the nineteenth century were classed as infidels and enemies of the faith because they advocated views of a changing earth.

The Opposition to Evolution

Organic evolution has also been attacked over and over. While the idea gained much headway during the heyday of Greek civilization, and especially at the hands of Aristotle, no further progress in evolutionary science was made for about eighteen hundred years. The chief inhibiting factor during this long period was the church, which at an early period had become saddled with a burden of doctrines and dogmas. Nothing new in the way of knowledge, unless it agreed with and supported these dogmas was tolerated, and advocates of new ideas were inquisitioned and in some cases put to death. During this long reign of dogmatism and religious bigotry little or no scientific progress of any sort was made and even religion itself became a cold, cruel and almost secular thing. With the domination of science by dogmatism there was associated not only a decline of science, but religion itself ceased to grow. It became static and in some respects lost its vitality. This is likely to happen again unless religion allies itself with science and draws from science new life and vigor.

During the long Dark Ages evolution languished and only a spark of life remained—a spark that was rekindled into a flame during the sixteenth and seventeenth centuries, when a general revolt against deadening authority occurred in Europe. Not only was the revolt directed against formalized and secularized religion, but there was a renewed interest in literature, in art, and in science.

In the field of evolution leaders rose up in England, in France and in Germany and a new struggle started. The authority of the church was too great, however, for the untrained evolutionists of the period to withstand. Several of those courageous men were inquisitioned and one of the ablest of them, Buffon, a Frenchman, was finally forced to recant his views about evolution. Be it said in his favor, however, that he stuck to his guns until weakened by old age. Another promising start was made by Lamarck a generation later. He devised and published a well-developed general theory of evolution and wrote a volume about it. It was met with disfavor by church authorities, but gained many adherents among men of science. When the question of evolution as opposed to special creation came to the official notice of the leading scientific society of the time (the Paris Academy) a debate was arranged between Cuvier, a great comparative anatomist, and Geoffroy St. Hilaire, a friend and follower of Lamarck. Cuvier was highly in favor with both civil and ecclesiastical authorities and it was as much his great influence as his ability as a debater that enabled him to win what then appeared to be a decisive victory for the creation idea. Thus was evolution seriously repulsed and forced to cover for nearly a generation.

The next open battle between evolution and dogmatism was the direct result of the publication in 1859 of Charles Darwin's great evolutionary classic *The Origin of Species.* This book created a real sensation in the world of science. Not only did it for the first time marshal an adequate array of evidences for the general principle of evolution, but it attempted to account for the causes of modification and of fitness. Scientific people were, with few exceptions, solidly behind Darwin and accepted his views, but the majority of the theologians of the period exhibited toward it an intense hostility, for they saw in this theory a contradiction of the account of creation in Genesis. The conflict was waged most bitterly, with Bishop Samuel Wilberforce (the Bryan of that period) leading the anti-evolutionists and Thomas H. Huxley acting as Darwin's spokesman, for the latter was an invalid and could not defend his views personally. Wilberforce used the same specious arguments, lacking in logic and flippantly witty, that are so familiar to all those who have heard his American successor. In one of his tirades against evolution Wilberforce ended his remarks by enquiring of Huxley, who was present as Darwin's champion, "whether it was through his grandfather or his grandmother that he claimed his descent from a monkey?" Huxley made the following famous and well-deserved retort which, without the change of a single word, would apply perfectly to a more recent leader of the anti-evolutionists:

"I asserted—and I repeat—that a man has no reason to be ashamed of having an ape for his grandfather. If there were an ancestor whom I should feel ashamed of recalling it would rather be a *man*—a man of restless and versatile intellect—who not content with success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by aimless rhetoric, and distract the attention of his hearers from the real point at issue by eloquent digressions and skilled appeal to religious prejudice."

The battle between the Darwinians and the followers of Wilberforce lasted for a decade. It was hot while it lasted, but it could have only one outcome, for truth ever prevails. The principle of evolution was soon accepted by intelligent people throughout Great Britain. It has come to be part and parcel of the intellectual life not only of scientists but of nearly all theologians. Today the British people express the greatest surprise that in an enlightened country, such as ours is supposed to be, and in an Age of Science like the present, there could be a recrudescence of, a resuscitation of, an issue so long dead and buried.

There is nothing new in the present attack except the introduction of legislative machinery on the side of one party in an attempt to prevent members of the other party from teaching their views. The fight was fair and open in England. It is unfair and carried on in ambush here. Laws can never settle scientific questions, nor can they be settled by popular vote. Some types of politicians believe that the ballot box can settle every issue, but this is an obsession characteristic of machine politicians alone and should be routed out before it infects the minds of others.

The Tennessee Anti-evolution Law and Its Consequences

The Tennessee law and the Dayton trial will, we trust, now appear in their proper perspective. We have shown that there is nothing new about the fear of science on the part of dogmatists and those who slavishly follow them, that there is nothing new about the whole anti-evolution issue. It is an ancient issue, for more than half a century considered moribund, raising its head to give one more gasp for life.

We are now forced to admit that even in an age of science when we had thought science had earned its right to a high place in our thoughts and was worthy of our highest respect, there are many who feel that it is a monster seeking to destroy religion.

What of the future? The fundamentalists openly claim that their victory in the Scopes trial is a prophecy of success in other states. Without intent to reflect on any state it may be said that the fundamentalists expect to make their fight in the following: Georgia, Alabama, Kentucky, Texas, Florida, Arkansas, Oklahoma, Mississippi. Even North Carolina, California and Minnesota are mentioned as possible fields for anti-evolution activities, but this seems unlikely in view of the strength of modernistic tendencies in these states. The selection of the above-mentioned commonwealths as fertile ground for the propagation of medieval theology constitutes an insult to their intelligence which should be vigorously resented. If any citizen of these states feels the stigma of being thus selected, let him place the blame on the fundamentalist leaders, for they, not the present writer, made this selection.

Opinions among scientists differ as to the probable outcome of the present organized campaign against evolution. The majority of them seem to look upon the whole thing as a temporary annoyance certain to be brushed aside within a short time. Others consider the menace of fundamentalism serious and are ready to fight it to the bitter end. Perhaps the prevailing opinion at present is that, with the death of Mr. Bryan, the momentum of the attack has been largely lost, that there is no leader to take his place who has the personal or political following or the knowledge of political manœuver necessary to bring about the passage of anti-evolution laws in other states. Moreover, it seems unlikely that any other state will desire to share with Tennessee the unenviable notoriety that is now its sole possession.

CHAPTER II

WHAT EVOLUTION IS AND WHAT IT IS NOT

What Evolution Means. The idea of evolution is as broad as the universe. It has to do not only with living things but with lifeless matter. It concerns itself with the infinitely great and the infinitely small. Broadly speaking, it is the philosophy of a changing universe as opposed to that of a universe at a standstill. It is the idea that the visible universe of suns and planets, as well as the invisible universe of atoms, is in a state of active change and has always been in a state of tremendous activity; that the conditions known to us today are the product of long series of orderly changes begun in the infinitely remote past. Thus there has been an evolution of the universe of nebulæ and solar systems; of our own particular solar system; of the earth and its bodies of land and water; of the chemical compounds that make up its rocks, its soil, its minerals and its salts in aqueous solution; of the particular chemical compounds that form the physical basis of life; of the various species of plants and animals of the past and of the present. Even the atoms that have for a long time been considered as unchanged and unchangeable ultimate materials have been shown to be composed of but two primal units, protons and electrons, which are nothing but positive and negative electric charges. All matter is merely a state of relative or temporary equilibrium of energy units. All is energy; all is motion of the most intense sort. If there is nothing but energy, motion and transformation, how could we expect the universe to be at a standstill, as the creationists claim?

Make no mistake about this point: we either live in a changing universe or an unchanging and unchangeable universe. If one accepts the view that the universe is changing, he accepts all that evolution implies, for evolution means no more than orderly change. The keynote of evolution is orderliness. All changes are part of one great process that has no beginning that we can comprehend and no end that is within the bounds of our limited powers of understanding. The vastness of it leaves us with a feeling of awe and reverence of the ultimate power back of it all and inherent in it. This feeling is nearly akin to worship. The scientist feels the inadequacy of his finite mind and the vastness and perfection of the whole scheme of things, and this, together with his aspiration to know the truth about it all, and nothing but the truth, is his religion. To him the processes of nature constitute the divine method of working out some vast and unknown purpose.

The only rival view of the universe is that God made everything in one brief period of time and then left it in a finished state to go on forever unchanged, that the sun and the stars are forever fixed and unchangeable, that the atoms are fixed and ultimate units, that all species of animals and plants were created in their present state and thus they will forever remain.

Let us not be deceived in this matter. There is no middle ground between the positions of creationist and evolutionist. Either the universe is undergoing orderly change or it is at a standstill, for any orderly change is evolution. The evolutionist sees vast slow changes occurring in the world today. He sees radioactive elements disintegrating to form other elements; he sees continents slowly rising or sinking, ocean beds doing likewise; he sees mountains wearing down by erosion and valleys filling up; he sees new types of animals and plants arising, some as the result of man's manipulations, others in adaptation to changed conditions due to transferal to new territory, still others in the course of breeding experiments conducted with a view to demonstrating that new characters arise in old species and are passed on by heredity to offspring.

All species of animals and plants are seen to be slowly changing today as the result of the addition of new characters or the loss of old ones. Some, in fact most, of the new characters prove to be less favorable than those characteristic of the species, and these cannot persist because the individuals possessing them are unable to compete with their fellows and therefore cannot pass on their characters. But occasionally a new character is good enough to survive and may be better than the old one. Such a character then comes to be a racial asset, and a small step in the evolution of a new species has been taken.

Man sees his world changing today, very slowly, to be sure, but none the less steadily. This slow orderly change of the present is all that he needs to explain the past. Merely assume that the past has been much like the present and we have all that we need to bring about evolution. If we fully understood the entire processes of inorganic and organic change as it is going on today we would have the key to all the past. The science of Genetics concerns itself with the small and large changes in organisms today and attempts to learn their causes and their means of perpetuation. When Genetics has solved the problems of the present it is certain that many of the problems of the past will yield to ready explanation.

We have tried to show what evolution means to the scientist. If we have succeeded in convincing the reader of the reasonableness of such an idea we have for the present accomplished our purpose. The main difficulty of the layman in understanding the essentials of evolution is associated with many unfortunate misunderstandings and misconceptions that have grown up in connection with the term "evolution." Now that we have explained in a general way what evolution is, it is our purpose to banish some of the prevalent misconceptions and mistaken ideas that clutter up our subject and make it difficult of acceptance by people who had not had the time to make a study of it.

What Evolution Is Not

1. *Evolution Not a Creed or a Doctrine.* It is not to be accepted on faith but only if it can be proved or shown to be reasonable. It is merely an idea advanced to explain a vast body of facts about the past and the present. The theory grew out of the facts and therefore must harmonize with the facts. If it in any respect fails to accord with the facts it must be abandoned or else modified so as to fit the facts. Evolutionists are not emotionally attached to the principle, but view it coldly and suspiciously, criticising its implications and seeking to learn all they can about its operations. If a new or

better explanation of things as they are should some day be discovered it would lead to an abandonment of the evolution idea, for the idea has no adherents who would cling to it after it proved inadequate.

2. *Evolution Not Incompatible With Religion.* Contrary to a widespread idea, evolution is not incompatible with religion. True science and true religion can never be in conflict, but error in either the one or the other may give rise to apparent conflict. It is deeply to be regretted that the enemies of science have tried to convince their hearers that science and religion are irreconcilable. This cannot be true, for not only are many men of science genuinely religious, but many theologians and great Christian leaders are in entire accord with the scientific views of the time. It is true that many scientists are purely materialistic in their conception of the universe and give little thought to religion. It is equally true that some of the doctrines, especially those of the fundamentalists, are directly opposed to the principles of science, but fortunately the representative scientist of today is heartily in sympathy with the true spirit of Christianity and finds no disharmony between his science and his religious faith. The progressives and the moderates in the fields of science and of religion are in close agreement. The whole conflict is between the extremists, the irreconcilables, of the two camps. R. C. T. Evans in his

book, *Man: What? Whence? Whither?* explains in a way that appeals to the writer as highly satisfactory how science and religion may be reconciled:

"I believe there are two great revelations to mankind. The one, the gradual unfolding to man's *mind* of the physical and psychical wonders of this marvelous universe. The other the gradual unfolding to Man's *spirit* of the knowledge and appreciation of the spiritual.

"Both revelations are true. In both cases all of our conclusions are not necessarily true. Our interpretations may err.

"The first revelation is the result of the keen observations of untold generations of men, upon the physical happenings around them. The second is the result of the deep insight into their own being, which exceptional spiritual men possess. Such spiritual men appear from time to time throughout the progress of humanity.

"The two revelations are not mutually exclusive. They are but different views of truth. One is almost limited to the universe, while the second not only concerns itself with this universe, but takes into account the spiritual state beyond.

"The discrepancies which loom so large to many people between the two revelations are due to our misinterpreting the one or the other; and, as mentioned above, each is colored and somewhat distorted by the medium by which it has been revealed, namely, 'the minds and spirits of men.' "

When science and religion are reconciled they must be reconciled more or less definitely along the lines indicated in Mr. Evans' statement. It is as fatal for the scientist to deny the realities of religion as for the religionist to deny the realities of science. The materialistic scientist may never have experienced the realities of religion—and these realities are matters of personal experience—but he can scarcely justify the statement that because he has had no contact with these realities, they therefore do not exist. Let us admit that religious experience is real and that science is real. Then the incompatibility disappears, for realities do not deny each other.

Science and the Bible. The whole controversy between science and religion has its foundation in divergent views as to the nature of the Bible. The fundamentalists, who now seem to be the chief enemies of science, sincerely believe that the Bible is the literal word of God, that the writers of the scriptures were inspired and wrote almost as a stenographer might write from dictation. The member of the state legislature responsible for draughting the Tennessee Anti-evolution Bill is said to have regretted his part in the passage of that measure when, for the first time, he learned that the Bible was a translation and was not originally written in

English. This mistaken idea of the Bible is doubtless prevalent among the less educated adherents of fundamentalism. It is indeed unfortunate that so many people have made of the Bible a fetish. Bible worship of this kind is an insidious form of idolatry.

Serious students of the sources of the books of the Bible have discovered that it is a collection of independent writings produced by many authors over a period of many centuries. It is highly improbable that the original manuscripts of any of these pieces of literature have been available to the translators, but earlier manuscripts than those available to the translators of the King James version—now practically universal in the United States—have been discovered since that translation was made, and it is now possible to make a translation more nearly in accord with the original writers' meaning than it was formerly possible to do. Moreover, it is common knowledge among expert scholars of the Hebrew language that many of the passages in our present version have been incorrectly translated or else are open to a variety of quite different constructions. This being the case, one sees at once the absurdity of the worship of the literal word of a particular translation.

To the biblical scholar the Bible consists of a series of Hebrew and Greek writings more or less arbitrarily compiled, many centuries after they were written, by men who judged them to be worthy of inclusion in the volume of religious literature which we now call the scriptures. These writings are in some instances historical, in others devotional, in others didactic. Some of the books are purely allegorical in intent and in style. Thus the Bible is primarily a textbook of religion and nothing more. It is a serious mistake to consider it an authority in the various fields of science. No one would think of going to the Bible for information about chemistry or electricity or engineering or any other modern science for there was no science at the time the scriptures were written. It is equally absurd to expect to find in the Bible authoritative statements about any great biological principle. To insist that the story of creation in Genesis is more authoritative than the principle of evolution is as unjustifiable as it would be to insist that the world is flat and that the sun goes around the earth, both of which ideas have biblical authority back of them.

In religious matters the Bible has high authority, for it is the most adequate and complete of all religious treatises, but it is by no means an encyclopedia of scientific or secular knowledge.

Many Christians of even the more conservative groups hold the view that is well expressed by the noted physician, Dr. W. W. Keen:

"The Bible is a textbook of Religion and not a textbook of Science. Like our common speech today, its language is popular, not technical. Sage and wayfaring men alike find in it guidance and comfort in this mortal life. . . . The 'Impregnable Rock of Holy Scripture' and the impregnable rocks of the geologist are equally God's handiwork and rightly interpreted must agree. . . .

"If man was a special creation, the Almighty was not limited to the lowliest forms of matter—the 'dust of the ground'—as material for the human body. He could have created a nobler, a more subtile, a more puissant and exalted stuff out of which to fashion man. The plan and structure and function of man's body would then supposedly have differed *toto coelo* from man's present body. Probably it would then have been free from the defects and deformities inherent in our animal body, and free from the diseases which it shares with animals. . . .

"Human life is the gradual unfolding of a majestic drama, covering æons of time. In its dawn we see man groping his way toward the light; then slowly but surely developing his intellectual life; and finally—how and when we know not now, but doubtless we shall know in the future, in the immortal life—the engrafting by the Creator upon his natural life of a moral and spiritual life for adoration and communion with his Heavenly Father.

This spectacle of wondrous power and beauty, this wondrous love of God for mankind, and the final lofty destiny of the Human Race—this is to me the most impressive vision of the ages."

In the mind of this speaker, and in those of many who believe as he does, there is obviously no conflict between science and religion. The two are beautifully and intimately blended into a harmonious and ennobling whole. While not all scientists nor all Christians are able to gain so happy a fusion of the two aspects of human life, it is plain that, for those who are attuned to the realities of both, as is Dr. Keen, the discord fades away and ultimate harmony and satisfaction is attainable.

3. *Scientists Are Not Abandoning the Evolution Principle and Casting About for Something Better.* The leading fundamentalists lay a great deal of stress upon the fact—for it is a fact—that there is no agreement among evolutionists as to the theories of evolution. Notice that the word "theories" is the one used by them. There is a vast difference, however, between the principle or law of evolution, about which all scientists agree, and the various theories devised to account for the exact processes and methods of evolution. Even about some of the causal theories of evolution there is practically complete agreement, but there are other theories about which controversy still rages. Among the most dis-

cussed and most unsettled of the causal theories is Darwin's theory of natural selection (survival of the fittest). Many specialists of today consider this theory untenable; others would adopt it in a highly attenuated form; still others advocate its complete validity. There *is* therefore discord among evolutionists as to the validity of *Darwinism,* for, technically speaking, natural selection and Darwinism are one and the same.

Unfortunately for clearness, however, newspaper writers and others have acquired the habit of referring to the whole evolution concept, the principle itself, as *Darwinism,* and this dual use of the term has caused much confusion in the public mind.

The late Mr. Bryan, for example, in his various anti-evolutionary books and papers spent most of his effort in an attempt to confute Darwin's theories of natural selection and sexual selection, obviously assuming that these theories are essential to the evolution principle. Had he only known it he could have saved himself much trouble, for the evolutionists themselves have abandoned the theory of sexual selection and have written volumes of criticism far more damaging to natural selection than anything that could possibly be written by one not at all conversant with the technique of modern biology. All of Darwin's selection theories might be wholly disproven without in the least affecting the general principle of evolution.

A striking instance of the failure to understand the unfortunate double use of the term "Darwinism" developed in connection with an address made in Toronto in 1921 by Professor William Bateson, one of the leading evolutionists of the day. Bateson, aware that he was addressing an audience largely composed of scientists, made a designedly frank and critical analysis of our present technical knowledge of the modes and processes of evolution, particularly pointing out the deficiencies in our knowledge of just how species arise. In concluding his address he made the following statement:

"I have put before you frankly the considerations which have made us agnostic as to the actual modes and processes of evolution. When such confessions are made, the enemies of science see their chance. If we cannot declare here and now how species arose, they will obligingly offer us the solution with which obscurantism is satisfied. Let us then proclaim in precise and unmistakable language that our faith in evolution is unshaken. Every available line of argument converges upon this inevitable conclusion. The obscurantist [enemy of science] has nothing to suggest which is worth a moment's attention. The difficulties which weigh upon the professional biologist need not trouble the layman. Our doubts are not as to the reality of evolution, but as to the origin of species, a technical, almost domestic problem. Any day that mystery may be solved."

In spite of this statement, obviously intended to forestall any such mistakes on the part of the Press, the *Globe*, a leading Toronto daily, came out the next morning with a signed editorial entitled "The Collapse of Darwinism" of which the following is an extract:

"To an audience rarely paralleled in Canada for scientific eminence and influence, the famous Professor Bateson, with amazing frankness, removed one by one the props that have been considered the very pillars of Darwinism. A scientist of international repute, one of the leading if not *the* leading evolutionist, of the day, he exposed the weaknesses of many of the leading planks in 'The Origin of Species,' and ruthlessly tore down one by one the once fondly believed links in the great chain of Darwinian evolution."

This statement, copied far and wide throughout the newspapers of America, was immediately seized upon by the enemies of science and was used in the present anti-evolution campaign by the leading fundamentalist and his followers. They told their audiences, without explanation or comment, that the leading evolutionist of the time had abandoned his belief in the theory and that the whole idea was discredited. Thus the address of Bateson, though not intended as such, came to be one of the chief weapons in the armament of the anti-evolutionists and is still being used.

As a matter of fact, there is no more likelihood that any evolutionist will or can revert to the doctrine of special creation than that any geologist will revert to the biblical idea of a flat earth or that any astronomer will revert to the biblical idea of a stationary earth in the center of the universe with sun, moon and stars revolving about it.

Not only all biologists of note, but all other men of science of recognized standing, are convinced of the validity of the evolution principle. The statement that evolutionists themselves are finding their theory inadequate and are abandoning it is therefore as false as any statement could well be.

4. *Man Is Not Believed to be a Descendant of Monkeys.* Perhaps the most prevalent idea of people uninformed about evolution is that evolution teaches that the present apes and monkeys, or animals like them, are the ancestors of man. No evolutionist has ever held such a view. The idea held at the present time is that man is a member of an order of mammals called Primates. All the present Primates, including monkeys, apes, man, have been derived from a generalized ancestral primate stock not at all like any of the present-day specialized end

products. For long ages the principal or central evolutionary branch of this stock has been the man branch. At an early time the monkeys were derived as a lateral offshoot from the central stock; later, the man-like apes split off and specialized along simian lines; still later, various types of primitive man-like creatures appeared some of which specialized in a manner different from that which has led toward modern man. These primitive prehuman Primates have become extinct. Man of the present is the end product of this main trend of Primate evolution. There is no indication that man has reached his ultimate evolutionary goal. (If this view of anthropologists is valid, it would be more correct to say that the monkeys and apes are degenerate descendants of the main line of Primate evolution that has given rise to man than it would be to say that man is descended from the monkeys or apes.) The relationship between man and the apes and monkeys is much the same as that between the pig, the cow, and the sheep. All belong to the Order Ungulata, but none is ancestral to the other. They are all descended from some very ancient generalized ancestral ungulate stock that long ago split up into the swine family, the cattle family, the sheep family and many others. The nearest relatives of the cattle family (which includes buffaloes, bisons, etc.) are such families as the sheep, the deer, the goats, and some others. These bear to cattle the same relationship that the apes bear to man. No closer kinship between man and the apes is claimed by the evolutionist.

5. *Has Man Never Seen the Origin of a New Species?* One of the most impressive claims made by the enemies of evolution is that scientists have never yet seen a new species originate. If new species arise from old species we should, they claim, be able to observe such an event, unless evolution has stopped. This argument always impresses the layman because his idea of what a species is and how species arise is so different from that of the scientist.

The "species" of the creationist is a sort of sacred and isolated category, sharply marked off from other "species." He is forced to admit that within the bounds of a given species there may occur all sorts of variation. The races of man, for example, are to him merely variations of a single species and do not represent real steps in the evolution of new species. In spite of all sorts of racial changes within the limits of the "species" the latter is believed to remain forever unchanged. It is difficult to understand how a *group* composed of numerous individuals can remain unchanged if the *individuals* themselves change in every conceivable way.

It is a great advantage to the creationist to know exactly what a species is and to be able to fix its limitations so accurately, for the experts in classifying species, the taxonomists, have never been able to define the term "species." It is merely a man-made term that has various limits when used by different taxonomists. What one calls a species another calls a variety or a subspecies. Various type specimens brought into museums have commonly been classed as "new species" only to be subsequently found to be aberrant members of old species. Man made the various taxonomic categories: races, varieties, subspecies, species, genera, families, orders, etc. He made them for convenience in arranging groups of individuals according to their degree of closeness of resemblance, but he is continually changing and renaming his species as he gains new information.

The truth about species is this. At present one species often blends imperceptibly into another so that it is difficult to determine where one leaves off and another begins. Many transitional forms exist that might arbitrarily be assigned to either of the two overlapping species. Of course there exist certain species that are distinct from all others, as for example man, for the genus to which he belongs has only one surviving species. When, however, a genus consists of a large number of species, many of which occupy contiguous geographic areas, the classification of distinct species is often a matter of arbitrary judgment and there is likely to be no concensus of opinion as to how many species the genus contains or as to what are the exact distinctions between one species and another.

There is, therefore, nothing really definite about the term "species." All we can say about it is that large numbers of individuals are more alike among themselves than they are like other individuals, that those in one locality are usually more alike than those in different localities because they are more nearly related. If then there are no sacred barriers between species there is nothing to indicate that each species was created as a fixed and unchangeable unit, but there is much to suggest that the various species of a genus have been derived or are being derived from a single parent species in which diversities have arisen and in which isolation may have served to encourage various forms of diversity.

Why then do we never see a new species originate? The mental picture that the creationist has of a species originating is nothing less than naïve. He demands that we must actually see with our eyes one species transforming itself into another. He probably visions the origin of man as an event taking place over night or at most within a generation. Some ape is supposed to have acquired human characters which he transmitted to his offspring; or else an ape is supposed to have had an offspring with human attributes. The idea of the origin of a species as an event capable of being actually observed by man is utterly absurd and childish. No man has ever observed the event of the birth of a new species because new species are not born that way.

How then do species arise? The science of Genetics has shown us that evolution proceeds by much smaller steps than that involved in the difference between two species. As was previously shown, the real evolutionary event is the sudden appearance in one generation of a new or changed character or the loss of reduction to vestigial condition of an old character. This is all that man can observe as an event. In a large species of continent-wide distribution the character changes (mutations) that occur in one area may be different from those in another, or else the surviving types in one region may differ from those of another because the varying environments of the two regions tend to favor different combinations of characters. In the course of thousands of years these slow divergent modifications result in two types sufficiently different to be assigned to two distinct species. Just when they reached this point no one could say. It is hardly probable that one day they are merely local varieties and the next day two distinct species. The event is not likely to be confined to one year or to one century; and that is why no biologist has ever actually observed the origin of a new species.

Since the term "species" cannot be accurately defined, it would be more accurate to ask the question whether man has ever observed the origin of new *kinds* of animals and plants. When the query is put in that way it may be answered by an unqualified affirmative. Man, by taking advantage of the changed characters of organisms and by selecting those new types he desires to preserve, has actually created large numbers of new *kinds* of animals and plants that are as different from the forms he started with as species in nature are different from each other. Think of all the different kinds of cattle, sheep, swine, grains, melons, fruits, flowers, that man has produced by coöperating with nature. Structurally speaking, there is much more difference between the skeleton of a bull-dog and that of a greyhound than between that of a wolf and that of a fox, yet both kinds of dogs have been derived from the same type of ancestral dog. The various fancy varieties of pigeons, although derived from one wild species, differ more radically in form and in plumage than do distinct species of wild pigeons in nature. "Yes," says the objector, "but all these domestic varieties are still members of the same species, for they are fully interfertile, while true species are in-fertile one with another." But this is not true. There are many instances of interfertility between members of distinct genera, let alone distinct species, and the writer himself has been able successfully to cross fishes belonging to different suborders and to get some healthy hybrids. On the other hand, some of the natural species of animals, so much alike that they can scarcely be distinguished, are entirely unable to hybridize.

This last statement deals a death blow to the pet idea of the creationist that God made each species as a distinct and delimited group incapable of mingling with other groups and therefore destined to remain distinct. The detailed study of species leaves one with quite the opposite impression, namely, that any large species is merely an assemblage of individuals, all different but some more alike than others; that all sorts of hereditary changes are occurring and that the group as a whole is becoming progressively split up into minor groups which form the beginnings of new species.

6. *Is Evolution a Mere Guess Unsupported by Facts?* To the anti-evolutionist hypotheses or theories are no more than "guesses." To quote the late Mr. Bryan, "the scientist that makes the most guesses is considered the greatest scientist." This puerile conception of scientific theories scarcely deserves serious consideration because it is so obviously

false. An hypothesis may in its inception be a sort of inspired guess, but unless it succeeds in explaining facts and is in accord with all the facts within the range of its application, it is discarded as a wrong guess. An hypothesis, however, that serves to explain and rationalize facts and that agrees with all known facts becomes then a *theory* or even a *law* or *principle.* Every great law starts out as an hypothesis, becomes after trial an established theory, and is then ranked as a law.

The evolution theory is not merely a "guess." It is supported by an immense array of evidence and has withstood the severest criticism of the scientific world for three-quarters of a century. It is now one of the best established of scientific laws and is the central principle that gives coherence and unity to the science of Biology. In the next chapter we shall state more fully what we mean when we say that evolution has been proven.

CHAPTER III

EVOLUTION AN ESTABLISHED PRINCIPLE

"The demonstration of evolution as a universal law of living nature," says H. F. Osborn, "is the great intellectual achievement of the nineteenth century. Evolution has outgrown the rank of a theory, for it has won a place in natural law beside Newton's law of gravitation, and in one sense holds a still higher rank, because evolution is the universal master, while gravitation is among its many agents."

This is not merely the expression of one man's opinion: it is practically the unanimous opinion of scientists today. "Why then," the doubter asks, "is it so difficult to prove that evolution actually has occurred?"

The difficulty faced by the evolutionist, though many times greater in degree, is the same one that faces the archæologist or the student of ancient cultures. He has the arduous task of reading the past from the traces of that past and from the vestiges of the past found in living organisms today. He is bound, like the archæologist, to interpret the conditions of the past in the light of conditions today. The study of the evidences of evolution follows the method of the historian and depends for its validity upon the same kinds of data, except that actual records written in human language are lacking. The records of evolution, however, are there for one who can read them and they have one advantage over records written by the hand of man in that they are all true and have never been tampered with or distorted in the hands of the historian. History, as all know, is never more than partially true, for every historian is biased by his patriotism, by his narrow perspective or by his personal prejudices. The main reason why it is difficult to prove the fact of evolution in a simple and direct way is that one must first learn the book of nature and have an intimate acquaintance with the facts of nature before one can understand the story of evolution or get any appreciation of the bearing or the force of the evidences brought forward in proof of evolution.

The writer labors under no delusions as to his ability to convince the confirmed creationist of the reasonableness and value of the evolution idea. To appreciate the true significance of the evidences of evolution requires long and arduous study. For this reason the only persons who really see the strength of these evidences are those who have made a special study of the actual materials. The more intensively one studies any field of natural science, the more necessary does it become to adopt the evolutionary point of view. The real specialists in science are the ones most firmly convinced that evolution is a valid principle. The layman can obtain at best only a faint idea of the real strength of the evidences of evolution. If this mere smattering of information seems to him convincing, how much more conclusive must be the great masses of data at the command of the numerous experts in biological science.

A timely warning to the lay reader of this little book may not be amiss. Don't expect too much in the way of cogent or direct proof of evolution. If you earnestly desire to know for yourself how strongly established is the principle of evolution, there is no royal road—no short cut—to the object of your desire. The only way to become adequately convinced about evolution is to become a serious student of the literature of the subject and come in contact with at least some of the materials that form its factual basis. Whether you study the fossils, embryos, vestigial structures, primitive structures in modern animals, or any other field of biological inquiry, you cannot long escape the necessity of adopting the idea of descent with modification—and that is exactly evolution.

Little wonder then that the opponents of evolution are so skeptical about it. They misunderstand its meaning and its implications, and know nothing about the facts upon which the principle is founded.

Many of them not only do not know the facts, but their minds are filled with false ideas about what they think evolutionists believe—ideas that have utterly warped their judgment. And worse than all this, they voluntarily close their minds to the facts, refuse to allow themselves to be enlightened, and even go so far as to say that the facts discovered by scientists are nothing but lies, guesses and interpretations. One must abandon such people to their fate, for there is no hope for them. This book is written not for them but for the open-minded.

One of the leading accusations of the opponents of evolution is that teachers of the subject fail to discriminate between what is fact and what is merely theory; that they teach the budding mind a theory under the guise of a fact; that they distort the facts into an appearance of agreement with the theory. This, if true, is a severe indictment against the teaching profession. Doubtless there are teachers who themselves have not learned to distinguish between fact and theory and therefore give false impressions to their pupils, for there are all too few teachers adequately trained to teach the subjects assigned to them. But this does not apply merely to teachers of biology. What we need to do is to educate our teachers of biology to the point where they are able to discriminate between facts and theories. There is much poor teaching in all branches of knowledge, but we are hardly ready at present to make poor teaching a crime, though this would be as sensible as passing laws forbidding the teaching of recognized scientific principles.

The Nature of the Proof of Evolution

There are two quite different kinds of evidence of evolution, one of which has to do with evolutionary changes in the past, the other with changes that are going on today. The evidences of changes that have taken place in the distant past must in their very nature be incomplete and to some extent circumstantial, though nothing could be more direct evidence of organic change than are fossils. There are of course no living eye-witnesses of events thousands or millions of years ago, nor are there any documentary records written in human language. Past events are, however, recorded in the rocks, in the structures of living animals and plants, in their embryonic development, in their distribution throughout the world, in their associations with one another, in their adaptation to their environment, and in their classification.

While the evidences of past evolution may be accused of being more or less indirect, this cannot be said of the evidences that evolution is going on today, for the proof that species are changing today is positive. Many new types have been observed to originate and to perpetuate themselves, though we are not yet quite sure as to why they arise and just exactly how the changes are passed on to offspring. The discovery that species are changing at a noticeable rate at the present time is in itself strong evidence that changes have occurred in the past, for even the convinced creationist would hardly claim that species have remained immutable throughout the ages only to begin to change since man began to study them with care. If we may merely assume that the present is the child of the past, that the same kinds of change noted today have gone on in the past at a more or less rapid rate than at present, that is all we as evolutionists ask. Grant merely that variation, heredity, isolation, selection, and adaptation to environment have been active factors in the past as in the present, and we need no more in order to account for the evolution of life as we have it today.

When we admit that some of the evidences of past evolution are indirect and circumstantial, we should hasten to add that the same is true of all other great scientific generalizations. The evidences upon which the Law of Gravity is based are no less indirect than are those supporting evolution. Both evolution and the Law of Gravity have acquired their validity because they have been able to explain, unify and rationalize many of the observed facts of nature. If certain facts entirely out of accord with either great principle were to come to light, it would be necessary to modify or to abandon them. There are many great scientific theories, some of the chief of which are the Nebular Hypothesis and its modern rival, the Planetesimal Hypothesis; the Molecular, Atomic, Ionic and Electron Theories of Physics and Chemistry; the Cell Theory of Biology; and others. None of these may lay claim to the same high degree of validity now enjoyed by the Principle of Evolution.

Yet, strangely enough, creationists, fundamentalists and other obscurantists have little difficulty in accepting most of these. For reasons which they themselves know best they choose to focus their whole attack upon the idea of evolution, and this in spite of the fact that several of these other theories can readily be shown to be as contrary to their avowed beliefs as is evolution.

The Principle of Evolution stands in the first rank among the great natural laws not only in its range of applicability but in the mass and cogency of the facts supporting it, and the extent to which it has been experimentally demonstrated. It is the one great law of life. It depends for its validity not upon conjecture or philosophy, but upon exactly the same sorts of evidence as do other natural laws.

Now this is the test of the validity of any scientific principle, that, when all the facts that have a bearing upon it are scrutinized in the light of this principle, these facts gain new significance, arrange themselves in systematic order, acquire coherency and unity. These services to scientific advance have been rendered as effectively by evolution as by any other known principle. For this reason alone, if for no other, evolution has earned a right to the world's respect. But in addition to all this, it must not be forgotten that evolution has been tried and tested for weaknesses in every conceivable way for more than two generations. And it has stood the test. What more could one ask of any theory or principle?

The exact nature of the proof of evolution is this: Using the concept of evolution as a working hypothesis it has been possible to rationalize and render intelligible a vast array of phenomena, which then become the facts upon which evolution rests. Thus classification comparative anatomy, embryology, blood tests, paleontology, geographic distribution and genetics, become consistent and orderly sciences when viewed from the standpoint of evolution, but when viewed in any other way they are thrown into the utmost confusion. There is no other generalization known to man that has the least value in giving these bodies of fact any sort of scientific coherence and unity. In other words, the working hypothesis works and is therefore valid until overthrown by a more workable hypothesis. Not only does the hypothesis work, but, with the steady accumulation of further facts, the weight of evidence is now so great that it overcomes all intelligent opposition by its sheer mass. There are no rival hypotheses in sight, for the creation theory cannot seriously be considered as a true rival, since it fails to accord with any of the facts and can neither explain nor rationalize anything.

The real proof of evolution rests upon its ability to rationalize and explain the facts of nature. When any large body of biological phenomena turns out on examination to be in accord with and to be explained by evolution, this body of data then may be cited as evidence for evolution. The evidences for evolution then consist of the facts that make up the following subsciences of biology listed below:

1. Comparative anatomy or morphology, the science of structure.
2. Taxonomy, the science of classification.
3. Serology, the science of blood tests.
4. Embryology, the science of development.
5. Paleontology, the science of extinct life.
6. Geographic distribution, the study of the hori-

zontal distribution of species upon the earth's surface.

7. Genetics, the analytic and experimental study of evolutionary processes going on today.

The Fundamental Postulate Underlying the Evidences of Evolution

A systematic survey of the evidences of evolution reveals the fact that they all are intelligible if based upon one guiding postulate, namely, that *true structural resemblance signifies blood relationship, and that the closeness of such resemblance runs essentially parallel with closeness of kinship.* In short, the more nearly alike individuals or structures are the more closely akin are they, and vice versa, the less alike they are, the less closely are they genetically related. The question must first be asked whether this postulate is justified; for unless we can rely upon its validity, little progress can be made toward a proof of evolution through the evidences. If, however, the postulate be granted, the way to such proof is simple and direct.

When we assume that closeness of resemblance is the result of closeness of kinship we are merely assuming the validity of the principle of heredity: that like tends to produce like. Every day we employ this principle in the common affairs of life.

When we breed a certain kind of fowl we expect to get offspring like the parents; when we plant a given kind of grain we expect a harvest of the same kind of grain; when sparrows hatch out young we expect nothing but sparrows of the same kind as the parents. If anything else should happen than what we expect, we would call it a freak of nature, a sport, or a miracle.

Again, we recognise the fact that members of the same human family are more alike among themselves than like members of other families. Brothers and sisters are usually more alike than are cousins, and first cousins are more alike than second or third cousins. Whenever we see two people whose resemblance is extremely close, so close as to approach identity, we at once assume that they are duplicate twins. As a matter of fact twins of this sort are not infrequent. Studies of their closeness of resemblance show them to be actually as nearly alike as are the two halves of a single individual. The explanation of this extraordinary resemblance is that two such twins have been derived from a single fertilized egg. No closer kinship is possible than this, and it is important to note that in this case we have the closest known resemblance associated with the closest possible kinship.

While fiction is full of instances in which two people quite unrelated are so much alike that they are able to exchange places without detection, actual cases of this sort are practically unknown. No instances of extremely close resemblance not based upon extremely close relationship are on record. When careful scrutiny and measurement of alleged "doubles" are made, they are seen to be much less alike in many ways than was supposed.

We would be much shocked if the young of a given species of sparrow were anything else but members of the same species as the parents. Logically, we assume that all sparrows of a given species are closely similar because they have been derived from common ancestors. If closely similar individuals (members of one species) are alike in specific characters because they have inherited these characters from common ancestors, it is only logical to assume further that closely similar races or varieties of animals or plants have been derived from a common species. Similarly, it must be logically assumed that closely similar species have been derived by descent with modification from an ancestral species, and have inherited their resemblances from this common source.

Once having taken this step—and this is the step the creationist refuses to take—we are on the road that leads inevitably to the evolutionary interpretation of natural groups. If the principle of heredity holds for offspring of the same parents, for races, for subspecies, for species, where are we to draw the line? It scarcely seems reasonable to admit that structural resemblance within a set of offspring from the same parents, those within a race, or those within a species are accounted for as a product of heredity, and to deny that equally plain resemblances between the species of a genus or among the genera of a family have any hereditary basis. Logically, it is impossible to draw the line at any level of organic classification and say that structural resemblance is the product of heredity up to this level, but that beyond this arbitrary level heredity ceases to operate.

The principle of heredity then is the only postulate that the evolutionist needs to assume in order to present his proof of evolution. And just here the evolutionist has the creationist on the hip, since the creationist lays much more stress upon heredity than does the evolutionist, for he believes in heredity without change through the ages, a sort of stereotyped heredity slavishly duplicating a fixed set of structural patterns without variation or improvement. Since both evolutionist and creationist find heredity indispensable, there should be little argument on that score. The argument is not about heredity but about variation. But let the reader beware at this point in the discussion, for if he admits the postulate here outlined he cannot avoid the inevitable conclusion to which it leads, that evolution is the only adequate explanation of the facts that we are now to present.

CHAPTER IV

EVIDENCES FROM COMPARATIVE ANATOMY AND FROM CLASSIFICATION

I. Evidences From Comparative Anatomy

The Principle of Homology. The basic principles of comparative anatomy are the principles of *homology* and of *analogy.* Anyone who has ever made a serious study of comparative anatomy must have been impressed with the fact that the animal kingdom is made up of several distinct assemblages of animals each characterized by a different type of architecture. Within any one of these grand divisions of the animal kingdom characterized by a common structural plan there occur almost innumerable diversities within the scope of the common plan. These major or minor departures from the ideally generalized condition inevitably remind one of variations upon a theme in music. No matter how elaborate the variation may be, the skilled musician recognizes the common theme running through it all.

This fundamental unity amidst manifold minor diversities of form and of function is looked upon as a common inheritance from a more or less remote ancestor. In animals belonging to the same group, and therefore having the same structural plan, organs are found that have in their final form little or no superficial resemblance, yet they are adjudged as homologous because, on more critical examination, it is found that they start out in development from the same embryonic rudiments, follow parallel courses of development for some time, and then set out on divergent lines of differentiation. In the end two such structures may have no external resemblance, yet in the finer details of their anatomy they show the closest sort of correspondence. Structures of this sort, no matter how unlike they appear, are said to be *homologous.*

A common example of homologous structures is seen in the fore limbs of various groups of backboned animals (vertebrates), such as those of man, those of the whale, those of the horse, those of the bird. Of these fore limbs those of man are by far the most generalized both in form and in function. Strangely enough, though man prides himself upon his high status among the animals, his fore limb is among the most nearly primitive limbs of land mammals. It is not modified for any single function, but remains generalized and therefore a versatile tool of the brain.

The flipper of a whale is a short paddle-like structure without any visible fingers, wrist, elbow or upper arm, but an X-ray picture of it shows it to be merely a very much foreshortened arm, with shoulder blade, collar bone, humerus, radius and ulna, wrist bones, and fingers. In nearly every detail of bones, muscles and nerves it is closely homologous with the arm of man. The difference is largely due to the fact that the whole thing is greatly shortened and broadened and the fingers are enclosed in a fleshy thumbless mit.

The wing of a bird, though used not as an arm but as a propeller-plane, is not so different structurally as one might suppose. Both arm and wing have closely similar muscular and bony architecture, the differences in the wing being due largely to the loss of the third and fourth fingers and a reduction of the thumb to a vestige. Both arm and wing start out their development as rounded limb buds, and it is not for a long time that they become noticeably different. The fore leg of a horse is a highly specialized running appendage especially designed for taking long strides on tiptoe. For the sake of lightness and strength all the toes except the middle one have disappeared, but some of the bones of the second and fourth toes are found in miniature under the skin, though they are not of the slightest use. Except for the great specialization of the middle toe of each foot, the toe nail of which is the hoof, and the loss or rudimentation of the other four toes, the horse's limb is quite homologous with the fore limbs of other land vertebrates.

The explanation offered for the fact that these structures, so different in appearance and in use, follow essentially the same structural plan is that the common plan has been inherited from some distant common ancestor. In each case hereditary variations (probably mutations) have occurred that have fitted in with some special feature of the environment. This implies descent with modification, and this is no more nor less than evolution.

An equally striking illustration of the principle of homology is furnished by the hind legs of vertebrates. The leg of man, a somewhat specialized walking appendage, is much less versatile than the arm, yet it is closely homologous with the latter. The hind limb of the whale is in some species entirely wanting in the adult, but in other species it is obviously present though reduced to a tiny useless vestige. Deeply embedded beneath the blubber of the pelvic region there lies a little handful of bones, recognizable as the incompletely developed bones of hips, thighs and sometimes of part of the shank. These bones are utterly functionless, for they still have the finer structure of bones, and bones have only one function—that of support for muscles. These bones are there, but their muscles have disappeared. If the whale was created in its present form, what is the significance of the handful of tiny unfinished and useless bones? The evolutionist believes that the whale inherits factors for hind limbs from remote terrestrial ungulate ancestors, but that one or more mutations have reduced the limb to a mere rudiment. The reason why a whale has the vestigial hind limbs is because he has never completely lost the hind limbs bequeathed to him by his ancestors.

The case of the whale just cited is in no way exceptional: it is, on the contrary, quite typical. Every species of higher animal has several, indeed many, of these *vestigial structures* that are homologous with functional structures of other forms. Snakes, for example, are typically limbless, but the python has small though clearly defined hind limbs, somewhat reduced in the number of digits but otherwise perfect, buried almost entirely beneath the scaly skin. Again, a strange bird of New Zealand (*Apteryx*) has no visible sign of wings, but if one carefully parts the soft feathers of the shoulder region he finds, lying flat against the body and entirely without any ability to move itself, a miniature wing, like the wing of a young chick before hatching. Even the creationist would hesitate to ascribe any functional value to this rudimentary appendage. These are a few typical cases of vestigial structures among animals. Thousands of similar cases could be listed without any difficulty. We shall not be able to give space to many further illustrations from the lower animals but must not fail to show that man is like all other animals in this respect.

Vestigial Structures in Man. According to the comparative anatomist, Wiedersheim, there are no less than 180 vestigial structures in man's body, enough to qualify him as a walking museum of antiquities. Prominent among these vestiges of the past are: the vermiform appendix; the short tail, with several vertebrae and a complete set of tail muscles; a complete set of paralysed muscles for moving the ears; a complete equipment of muscles for erecting the hair of the scalp (now functionless in most people and of doubtful value to any); gill slits in the embryo; miniature third eyelids; a complete coat of fur on the body of the fetus that is shed before birth. The little toe and the wisdom teeth are example of structures on the wane. Let us examine two or three of these organs in a little more detail.

The tail of man, and similarly of the anthropoid apes, is by no means absent. Man has a very obvious tail, but it is not visible externally except in rare instances. In the adult the tail is represented merely by a short series of four or five vertebræ more or less fused together. This rudimentary tail is a little better developed in the apes. In both man and the apes the tail develops much as it does in other mammals and at one stage is about a fifth as long as the rest of the body, longer even than the legs. At this stage the tail is capable of being moved by muscles that commonly dwindle away, but in rare instances persist in adults and are described by anatomists as anomalies. The creationist may well be asked to explain why man was endowed with an embryonic tail and why he retains an obvious vestige of the structure so characteristic of lower orders of animals. The evolutionist has no other explanation of the tail than that man inherits a tail from tailed ancestors, but that modification has resulted in its reduction to a useless rudiment.

The muscles of the ears are equally significant. Anatomists report that in the case of fresh human bodies it is possible to demonstrate a complete set of muscles homologous with those that serve to move the ears in other types of mammals that need to move the ears to detect the direction of sounds. These muscles in man are so delicate and soft—without function except in the occasional person who has the rare accomplishment of wiggling his ears—that a few hours after death they disintegrate.

Finally, it may be said that various types of relatively hairless mammals, including man and the whales, the fetus at about the beginning of the last third of the period of pregnancy is covered with *lanugo,* a heavy coating of soft furry down. This coating is lost before birth and has no conceivable function in the fetus. It can mean nothing else than that man is descended from some ancestor that had use for a complete coating of fur, and that in the course of time the inherited fur was lost early in development, leaving man an almost naked animal needing to cover his body with artificial clothing.

Homology versus Analogy. Almost as striking evidence for evolution is afforded by instances of *analogous* structures. Numerous cases are known in which animals quite different in most respects have one organ strikingly similar in appearance and function. The eye of an octopus, for example, has a chorion, a lens, a retina, an optic nerve (at least there are structures that have received these names). In general, the octopus eye looks much like that of a fish. As optical instruments the two kinds of eyes seem to perform much in the same way, but there the resemblance ends, for in every structural respect the two organs are different. Not one part of the octopus' eye is homologous with that of a fish, for they all arise from different embryonic primordia, have a different course of development and have quite different anatomical relations to surrounding structures. All *analogous* structures of this sort must be sharply contrasted with homologous structures, for they are not derived from common ancestral structures but have been moulded out of entirely distinct materials to subserve a common function. But this also implies modification in adaptation to changing environmental demands and is therefore an argument for evolution.

Connecting Links. If one group of animals has been derived by descent from another, it is obvious that there should be some species more or less intermediate between the two groups—species exhibiting the characteristic features of both. Large numbers of these connecting links have been found among the fossils and not a few are still living today. Almost every large group of animals has some members that are known as primitive forms or prototypes. These forms have apparently lagged behind the main body of the group to which they belong and on that account have retained some of the features of the ancestral group from which they have been derived. For example, there is a series of species of primitive annelids or segmented worms (a group to which the earthworm belongs) which serve partially to bridge the gap between the annelids and the next lower group, the flatworms. One genus of these primitive annelids, *Dinophilus,* consists of several species, some rather more like flatworms than annelids, others rather more like annelids than flatworms. The genus is so evenly balanced between two great groups that some authorities have included it in one group and others in the other group, while still other biologists are inclined to place these worms in a group by themselves.

Again, there is a genus of primitive centipedes, called *Peripatus,* which possesses about as many annelid as arthropod features, and thus forms a perfect connecting link between the worms and the centipedes, the latter being also closely joined by connecting links with the insects.

Among vertebrates there are many notable examples of connecting links. We may mention first those extraordinary fishes, known as lung-fishes, that have both the gills of fishes and the lungs of land vertebrates. And second, we may call to mind the curious egg-laying mammals of Australia and New Zealand, which, though mammalian in most respects, lay eggs, hatch their young by means of their body heat and have in addition many other distinctly reptilian traits. These must serve as mere samples of connecting link types. The significance of such types is this: that the animal kingdom does not seem to consist of sharply defined groups, as we should expect it to be if each group were created independently of all others, but each group seems to be more or less closely connected with one or more others. This is what we should expect if one group has been derived by descent from another or both from a common extinct ancestral group.

Comparative anatomy is today a mature and well organized science and involves a knowledge of much technical data that cannot here be given. No one but a trained anatomist is in a position to appreciate the extent to which this subject is dependent upon the principle of evolution. Without evolution as a guiding principle comparative anatomy would be a hopeless jumble of meaningless and puzzling facts; but with the aid of evolution, and especially the subsidiary principle, homology, it has grown to be one of the most scientific branches of biology. This may be taken as an illustration of the nature of the proof of organic evolution: (that, when it is used as a guiding principle, it not only serves to explain the facts of the subject, but reveals new facts and binds them all into a coherent and consistent unit.) In a word, it changes a jumble of miscellaneous information into a science.

II. Evidences From Classification

The object of classification is to arrange all species of animals and plants in groups of various degrees of inclusiveness which will express as accurately as possible the genetic or blood relationships that actually exist. Thus we place together in one species all animals that are more alike among themselves than they are like other kinds of animals. It has already been shown (p. 32 ff.) that the limits of many species are ill-defined and that what one taxonomist calls a species another calls a local variety. The term "species" is, however, a convenient name for certain groups of animals and plants and cannot well be ignored if we are to classify organisms at all. We first decide to place all members of a variable group of individuals in a species because, in spite of their individual differences, they have many characters in common. As an example of the procedure of the taxonomist, let us take the following example:—the European wolf is a kind of animal recognized as a species and given the specific name *lupus* (Latin for wolf). There are other kinds of wolves each given another specific Latin name. Then there are dogs, which are known to be merely modified domestic varieties of wolves. All these wolf-like species are placed in one genus, *Canis* (meaning dog), the assumption being that they owe their similar features to a common ancestor. Several other genera of wolf-like animals, such as foxes and jackals are placed with the genus *Canis* in a family of genera known as *Canidæ,* the assumption being that these genera have been derived from a more remote and more generalized wolfish ancestor. Other families, such as the Cat Family *(Felidæ)*, the Bear Family *(Ursidæ)*, and several other families of terrestrial beasts of prey, constitute the suborder *Fissipedia.* This group together with the marine beasts of prey, seals, sea-lions, walruses (suborder *Pinnipedia)* constitute the mammalian order *Carnivora.* This and several other orders of animals with many features alike are combined to form the class *Mammalia,* which is one of the several classes constituting the subphylum *Vertebrata,* a branch of the phylum Chordata. A phylum is one of the grand divisions of the animal kingdom and is made up of all those kinds of animals with the same broad general structural plan, the common features of which are believed to have been possessed by the most remote generalized ancestral type.

The underlying assumption of classification is that degrees of resemblance run parallel with degrees of kinship. We have already justified this assumption, for it merely means an affirmation of the validity of the principle of heredity.

When we have completed the classification of any large group of animals, such, for example, as the vertebrates or backboned animals, the result is most conveniently represented as an ancestral tree with one common main branch, secondary branches for classes, tertiary branches for orders, and successively smaller branches for families, genera, species, varieties. The terminal twigs are the races and the leaves the individuals. This tree-like arrangement is exactly what one would expect if a group of animals has been derived by descent with modification from a common ancestor. Such a tree is a true genealogical tree. If this strikingly genetic grouping of organisms is merely a part of the plan of special creation, it is strangely unfortunate that it speaks so plainly of descent with modification.

Man's Place in the System of Classification

The taxonomist has no difficulty at all in placing man in the system of classification. Man, in fact, is relatively easy to classify as compared with hundreds of other species of animals, many of which have affinities to established groups so obscure that it is difficult to find a place for them in the system. Man belongs to the species *Homo sapiens*. Anatomically the genus Homo is very close to the anthropoid apes. Bone for bone, muscle for muscle, and in many special details they are so much alike that even the novice in comparative anatomy can scarcely fail to note the homologies at a glance. Man is many degrees closer to the anthropoid apes than the latter are to the typical monkeys, yet the creationist insists upon placing man in biological isolation as a creature without affinities to the animal world. If man is a creature apart from all other animals, it is strange that he has so much in common with them; that he fits so readily into their system of classification; that his processes of reproduction are exactly those of other animals; that his embryonic history parallels step for step that of the apes and can hardly be distinguished from the latter till near the time of birth; that his processes of nutrition, respiration, excretion are essentially the same; that even his fundamental psychological processes are of the same kind, though differing in degree of specialization, as are those of lower animals.

Comparative anatomists recognize man as a vertebrate, for he has all the characteristic features of that subphylum. He is obviously a mammal, for he complies with the qualifications of that class in having hair; in giving birth to living young after a period of uterine development; in suckling the young by means of mammary glands; in having two sets of teeth, one succeeding the other; in having teeth differentiated into incisors, canines and molars; and in some twenty other features that differentiate mammals from other classes of vertebrates. Among mammals, man belongs to the well-defined order of Primates, an order anatomically about halfway between the most generalized and the most specialized of the mammalian orders. Apart from his extraordinary nervous specialization, man is a relatively generalized mammal as compared with the most highly specialized mammals, the whales.

The older taxonomists conceived of man as the pinnacle of evolutionary progress and assigned to him the topmost branch of the genealogical tree. Other animals were placed according to their resemblance to man, those least like man being placed lowest in the scale. According to this method of classification the whales were placed lowest among the mammals. Now, however, since man is getting away from this anthropocentric point of view, taxonomists are rearranging the orders of mammals scientifically, with the Insectivora the lowest order, the Cetacea (whales) highest, and Primates about midway between the two extremes.

The order Primates consists of two suborders—Lemuroidea and Anthropoidea. The lemurs or "half-apes" are small arboreal animals with a combination of shrew-like and monkey-like traits. They help to bridge the gap between Primates and Insectivora, the primitive order of mammals from which the Primates are believed to have taken their origin. The Anthropoidea (meaning man-like) comprises three families: the *Hapalidæ* or marmosets, the *Cercopithecidæ* or true monkeys, the *Simiidæ* or anthropoid apes, and the *Hominidæ* or men. The Hominidæ consists of four genera according to some authorities and only two genera according to others. Commonly we distinguish as one genus of Hominidæ, *Pithecanthropus,* the Java ape-man. The other genus recognized by all is the genus, *Homo,* of which only one species is now living and several species extinct, including *Homo neanderthalensis* (the Neanderthal Man), *Homo heidelbergensis* (the Heidelberg Man), *Homo dawsoni* (the Dawn Man), and others.

The species *Homo sapiens,* besides some extinct races (Cro-Magnons, Grimaldis, etc.), consists of at least four subspecies or major varieties (called species by some anthropologists), each consisting of numerous minor races and admixtures of these. This high degree of diversity within a species is in itself strong evidence of rapid recent evolution. If in about 6,000 years, as the creationists claim, all of these very different kinds of men have been produced as the descendants from one man, this means that all this diversity has developed in about 200 generations, a remarkably short time as world changes go. This would mean an evolutionary process far more rapid than the most ardent geneticist would expect to get in a hundred times as many generations of lower organisms. In this instance then, the creationist, if he admits that all men today are descended from Adam about 6,000 years ago, outrivals any evolutionist in his claim of speedy evolutionary change.

CHAPTER V

EVIDENCES FROM BLOOD TESTS AND FROM EMBRYOLOGY

I. Evidences from Blood Tests

The methods of classifying animals outlined in the previous chapter depend upon relatively gross criteria (homologies) as compared with the method of classification by blood tests, a delicate chemical method of determining animal relationships. The blood of an animal is a sort of concentrated extract of its entire being and the chemical composition of the blood of different animals differs for each species. Those that are most closely related have the blood most alike chemically and these least closely related have little blood resemblance. The beauty of the blood test method is its delicacy and its quantitative accuracy. By means of it one can tell just how closely related two kinds of animals are—not merely that they are related in some degree.

Thus, if we wish to find out what animals have blood most nearly like that of man, we go about it as follows: Human blood is drawn and allowed to clot, thus enabling one to separate the liquid colorless serum, which is the true essence of the blood. This is injected in small doses at varying intervals into the veins of a rabbit or some other animal. In time the blood of the rabbit is said to be fully sensitized. By this we mean that a specific material has been built up in the rabbit's blood that is opposed to or tends to neutralize or precipitate human blood serum. This anti-human serum of the rabbit's blood may now be used as a delicate test for human blood, for when mixed with minute traces of human blood (even blood stains dissolved in salt solution will do) an immediate and definite white precipitate is formed. When this anti-human serum is added to the blood sera of anthropoid apes it gives a similar precipitate, but less quickly and in less quantity. No other blood gives so sharp a reaction with anti-human serum as does that of the apes. Next in order of speed and abundance of precipitate come the monkeys, and then the marmosets. Even the lemurs give a faint precipitate, but it requires quite a long wait for it to appear.

The tests further indicate that if strong enough solutions are used and time enough allowed, one can establish the degrees of relationship among all groups of mammals, and these agree closely with the relationships based upon structural resemblance (homology). Not merely this, but in many cases where the relationships suggested by homology seem rather vague and far-fetched, these conjectures have been strongly confirmed by blood tests. An interesting instance of this is furnished by the whales, mammals so unlike other orders of Mammalia that only the vaguest suggestions of their true affinities have been revealed by their anatomical features. For a long time it has been suspected, on anatomical grounds, that the whales were profoundly specialized derivatives of the order Ungulata (hoofed mammals). Now the blood tests strongly confirm this hypothesis and even go as far as to indicate the Swine family of ungulates as the one branch with which the whales seem to have the closest affinity.

The serological methods used in blood testing are complicated and require much refinement of technique. For this reason few scientists have acquired the necessary skill to use blood tests with authority. The best results so far obtained, however, are so definite and clean-cut that there is no reason to question their authenticity. Much further light is likely to be shed upon the obscurities of taxonomy by an extension of this technique. Already most of the larger groups of animals have been tested and in general the affinities indicated closely parallel those based on homology. There is, however, no exactness about this parallel; nor could we expect such to be the case. For that matter, there is no exact parallelism between classifications based on teeth and that based upon feet, or between any other two unconnected systems. No two systems of an organism exactly keep pace in evolution. One may remain relatively conservative while another undergoes pronounced specialization. Of all systems the blood seems to be the most conservative and to have retained longest its ancestral condition. It is on this account that blood tests so often reveal relationships that can scarcely be determined in any other way.

Far more important than any information revealed directly by the blood tests themselves is the fact that the two modes of testing degrees of relationship—that of homology and that of blood precipitation—so closely coincide in their results. Suppose for the sake of argument that the two gave quite opposed and disharmonious results, what a blow to our confidence in the validity of evolution! Conversely, how greatly is our confidence in evolution increased when the two entirely different methods agree in their indications as to the genetic relationships throughout the entire animal kingdom!

II. Evidences from Embryology

Although it is well, for the sake of clearness, to present the evidences of Comparative Anatomy and those from Embryology as two separate bodies of data, it is by no means easy to keep them separate in one's mind. These two branches of biology are inseparable, for one must be interpreted in the light of the other. Comparative Anatomy is supposed to deal exclusively with structures of adult organisms, but whenever there arises a question as to the homology of adult structures it is customary to study the embryonic origin and course of development of the structures in question. If structures are really homologous they come from equivalent embryonic rudiments, and this is, by definition, a test of homology.

We must also bear in mind that a type of animal is really not adequately denoted when its adult anatomy is described, for the characters of the species are also involved in the kind of egg and spermatozoön it has, in the pattern of the cells during the earliest period of development, in its particular modes of forming its body layers, and in its special modes of differentiating its characteristic organs. In brief, a species is adequately defined only when a full description of its entire developmental history is given. Very closely related species keep step nearly all the way and diverge only toward the final stages of their development; distantly related forms diverge and follow different paths of differentiation early in their course; while unrelated forms may have little or nothing in common from the beginning except that they all arise from a single cell.

The general rule is that the more advanced groups of organisms travel a much longer journey before reaching their destination than do organisms of lower status. In many instances certain early stages in advanced organisms present an unmistakable resemblance to end stages of lower organisms. Furthermore, during the long period of development of one of the highest organisms, say a vertebrate, the various steps taken often remind one strongly of the end stages of a whole series or lower forms beginning with the simplest and proceeding step by step higher and higher up the scale. This means, as one can readily see, that the process of development of one of the higher organisms gives a sort of rough-and-ready review of the characteristic features of many lower groups that may be thought of as ancestral to it. This fact has so impressed embryologists that they have embodied it in the form of a law, the *biogenetic law:* that ontogeny (the development of the individual) recapitulates phylogeny (the evolution of the race). In less technical language, this means that the various stages in the development of an individual are like the various ancestral forms from which the species has been derived, the earliest stages being like the most remote ancestors and the later stages like the various more recent ancestors. In still other words the idea is stated as follows: *the developmental history of the individual may be regarded as an abbreviated résumé of its ancestral history.*

Now if we could accept this statement at its face value, all we would need to do in order to discover the exact ancestral history of any species of animal would be to study the whole development of an individual of the species. Unfortunately it is not so simple a matter as this. In the first place, it must be obvious that no embryonic stage of a higher animal could be truly equivalent to an adult of a lower group, for an embryo is always unfinished. But we can say this: that many embryonic structures of higher organisms strongly remind the embryologist of some of the adult features of lower groups. In the second place, we must remember that embryos and larvæ (independent embryos) of higher forms have a most important and immediate concern with the difficulties of keeping alive in an inimical environment and that they must adapt themselves in various ways to the environment in which they live if they are to survive. On this account the outstanding characteristics of embryonic and larval stages are those particular structures that have no significance for adult life, but are merely temporary or transient adaptive mechanisms. These take up so much room and so distort the primitive form of the individual that they commonly mask the more fundamental structures to such an extent that one finds it well nigh impossible to decipher the ancestral record. In the third place, different systems of organs develop at different rates, so that when one system has reached an advanced state of development another is still in a rudimentary state. Thus, in the development of fishes, the nervous system is far along in its course of development before the circulatory system has even begun to establish itself. At such a stage as this the embryo could not possibly resemble any adult ancestor, for an organism so discordant could not lead an adult life.

The biogenetic law in its original form is therefore not valid. We must modify it to fit the facts. Ontogeny tends to repeat phylogeny, but only within distinct limits is the law valid. Organisms inherit from their ancestors not only their adult characters but their embryonic characters. But not all of the embryonic characters of all ancestral stages can be repeated, for the essential steps in evolution have in many cases involved a substitution of new embryonic structures for old ones. Hence new and old cannot both appear, for the new displaces the old. Thus many ancestral characters disappear from the developmental history of a higher organism. Sometimes, however, the evolutionary change does not involve the substitution of a new for an old character, but the mere loss of an old one or a reduction of it to a rudiment. Frequently the reduction merely means that the structure makes a promising start as though destined to produce a functional organ, but instead of going through with it, stops developing and remains for life in an unfinished or embryonic state. Examples of this type of thing have already been described in connection with vestigial structures, for example, the hind limbs of the whale or of the python, the wings of Apteryx, or the tail of man.

The biogenetic law works out very beautifully when we apply it to one system at a time instead of to whole organisms. Thus we find that the human system of blood circulation in the course of its development passes through a whole series of stages that are much like the adult stages of a series of ascending vertebrate classes. The heart arises from a sheet of mesoderm tissue lying beneath the pharynx. It has at first the form of two nearly straight troughs which fuse for part of their length to form a single median tube. The single-tube heart is like that of the primitive chordate, *Amphioxus.* Later the single tube differentiates in front into an auricle and behind into a ventricle and takes on the condition of a fish. The auricle next divides lengthwise into two chambers like the heart of a frog. Then the ventricle divides and the heart becomes four chambered like that of the mammals. The main arteries and veins of the head region are at first laid down with reference to the gill arches, which are present in all vertebrates but do not have any relation to gills except in aquatic vertebrates of the fish grade or in the larvæ of amphibians. In the higher vertebrates everything develops as though for a branchial (gill) mode of respiration, but later the whole architecture of this region has to be remodelled to fit it for lung respiration. While the arteries and veins are in the form to supply gills there appear in the neck region of the human embryo four pairs of crevices exactly like the gill slits of fishes. Three of these, however, never break through to the pharynx as in fishes, but disappear without ever functioning. The fourth gill slit becomes profoundly modified into the Eustachian tube, which connects the pharynx with the middle ear. The transitory gill slits of man can have only one sensible interpretation: that these structures appear at an early stage because they are inherited from a remote ancestor that had a use for gill slits, but adaptive demands have caused the suppression of these organs in favor of more useful structures.

Nothing is to be gained by multiplying examples of this sort. One could do for each system of the body what we have done for the circulatory system and the result would be the same. The embryology of man is pretty thoroughly known in spite of the difficulty of obtaining earlier stages. Step by step it is almost precisely like that of other Primates, especially like that of the anthropoid apes, and it is only in later stages, principally postnatal stages, that man and the apes markedly diverge. Possibly there may be experts who can see the points of difference at earliest stages, but this is doubtful. The really striking thing is that the embryonic histories of man and of the apes are so very much alike. So close a resemblance is found only in species that are members of the same ancestral stock, for they have both inherited the characteristic features of their development from common ancestors.

In conclusion we may say that, of all the evidences of evolution, those from embryology are the most technical and difficult to popularize. We have contented ourselves with the briefest of statements of this important field because one really needs a course in embryology to understand this type of evidence. It is interesting, however, to know that among professional biologists the embryological evidences of evolution rank extremely high, perhaps highest of all, for there have never been any suggestions in this field from the creationists. They either know nothing about the embryological evidences or see no way of explaining them on biblical grounds. Those who have had the facts forced upon their attention have no recourse but to deny them, and this is the only way out other than to accept for them an evolutionary interpretation. Those who deny the facts are hereby challenged to spend a few days with the microscope under the direction of a good embryologist. Only a blind man could then deny the facts we have here described.

CHAPTER VI

EVIDENCES FROM PALEONTOLOGY AND GEOGRAPHIC DISTRIBUTION

I. Evidences from Paleontology

Paleontology may be defined as the science of ancient life. Its materials are largely fossils, the preserved actual remains, petrifications, moulds and traceries of the bodies of animals and plants that once were alive. Fossils are real; they cannot successfully be explained away. The suggestions of the creationist that fossils are the mistakes made by the Creator and buried deep out of sight, or that they were made by the devil to deceive man, are not likely to impress intelligent people.

Various Kinds of Fossils. The best fossils we have are the preserved bodies of extinct animals, such as the complete remains of many species preserved in asphalt lakes, bodies of mammoths frozen in arctic ice or tundras, bodies of hundreds of extinct species of insects embedded in amber. Next in degree of perfection are petrified fossils, in which the organic matter has been replaced particle by particle by mineral matter. Finally, many fossils consist of casts of the external form of animals due to their lying in mud and leaving their impress.

If evolution has taken place and samples of every species that ever lived were preserved in the places where they lived, it would still be a most formidable task to work out complete fossil pedigrees of all species living today. Also we might get little further light on the actual causes of the changes observed. The real situation that confronts the paleontologist is this: We have so far found samples of no more than perhaps one per cent of the species of the past, a mere random sampling. The chances of any group being fossilized and the fossils remaining undisturbed and in a region available for study are extremely small. Considering these and other reasons why we must expect the fossil record to be very incomplete, it is indeed remarkable that so much of it has been so satisfactorily worked out. We really should marvel at the completeness and richness of the data already at hand and look forward with eagerness and confidence to what the future has in store.

Age of the Earth. One of the main differences of opinion between evolutionist and creationist has to do with the mere matter of time involved in the history of life. The creationist thinks that the whole universe started about 6,000 years ago, while the evolutionist thinks in terms of billions of years. According to the most recent computations based on the rate of radium emanation, a billion years have elapsed since the earth reached its present diameter. Various estimates as to the time since life first appeared on our planet range from 50,000,000 years to about ten times that. Even the lower figure gives us ample time for any sort of evolutionary change, no matter how slow.

The Earth's Strata as Time Markers. The crust of the earth is made up of a series of horizontal layers of rock varying in composition and in thickness. The materials tell us the conditions under which the rock has been formed. No one is likely to dispute the statement that the bottom layers were formed first and are therefore the oldest and that the order of superposition of the layers is an index of their relative age. Of course there are regions of the earth's crust where tilts have occurred and where strata are turned edgewise to the surface, but, when studied by the expert in connection with the surrounding undisturbed strata, the true order may be determined with accuracy. In this place it would hardly be appropriate to discuss the modes of rock formation and methods of fossilization. Let us simply say that we use the data of the geologist as a means of determining the age and the sequence of extinct species found preserved in fossil form in the various rocky strata.

The Main Facts Revealed by the Fossils

(1) None of the animals of the past are the same as those of today. With the single exception of a species of brachiopod (*Lingula*) that may be the same now as it was in the Cambrian, there are no species living today that are identical with earliest fossil species.

(2) The animals and plants of the oldest geological strata represent all of the existing phyla except the vertebrates, but these early examples of the various phyla are all relatively generalized as compared with the modern representatives of the same phyla.

(3) As we pass from lower to higher strata of rock the contained fossils show a gradual progression from more generalized and simpler organisms to more specialized and complex organisms.

(4) Enormous numbers of groups of animals and plants have now no modern representatives. These extinct groups ran their course of specialization and completed their evolution long ages ago, leaving no descendants.

(5) Only the most generalized relatives of these highly specialized end products of evolution had enough plasticity to meet the vicissitudes of world changes.

(6) It is common to find a new kind of organ-

ism getting a start toward the close of a great geological period during which vast climatic disturbances were taking place. Such a new group, if it succeeds in weathering the changes incident to the passing of one geological age into another, commonly becomes the dominant group of the next period, presumably because it arose in adaptation to the newer conditions and is therefore at home in the new age.

(7) The evolution of the various classes of backboned animals (vertebrates) is more fully known than that of almost any other group for the reason that this group arose within relatively recent times and during a period when fossils are abundant. Of the vertebrates, the mammals are best represented and show the most complete fossil pedigrees; this, because they are the most recent in origin and their remains have been least disturbed.

(8) Many practically complete fossil pedigrees have been worked out, connecting familiar modern animals with simpler, more primitive ancestral types. Some of the best of these pedigrees are those of the horse, the elephant, the camel, the rhinoceros, and many others. The pedigree of the horse is here given simply as a sample. Any one of a score of others would be equally good for the purpose.

Pedigree of the Horse. The horse family (Equidæ) has evidently evolved on the American continent for their fossil remains are largely found there. The conditions under which the group developed were those of dry, grassy, open plains. Life on these plains has evidently involved much swift running and a diet of coarse grasses. The horses have adapted themselves chiefly to these two conditions. Thus the limbs have become greatly elongated and the foot raised on tiptoe. The middle toe has become the most important and best developed, while the other toes have been reduced to vestiges or entirely lost. At the same time the grazing machinery has been gradually perfected. The neck and head have greatly increased in length enabling the mouth to reach the ground without bending the knees, while the molar teeth have become longer to compensate for severe wear due to grinding coarse food, and have acquired a complex grinding surface. While these changes have gone on, the size of the members of the group has steadily increased from the tiny *Eohippus,* the ancestral horse of the Lower Eocene, which was no more than eleven inches tall at the shoulder, up to the modern horse which measures about sixty-four inches. All intermediate sizes are found between these extremes.

These changes have taken place little by little, each succeeding age showing horses a little larger and a little more advanced in the specializations characteristic of horses. There is a long and beautiful series of intermediate forms linking the present with the distant past. The sequence of these stages in the rocks is precisely what one would expect to find on the theory that each one has been derived from the next below. A few of the more important steps in the pedigree of the horse may be mentioned.

The first member of the horse family appears to have been *Hyracotherium*, a primitive ungulate exhibiting the first equine tendencies. This together with *Eohippus* lived in North America during the Lower Eocene. In *Eohippus* the forefoot had four hoofed toes of nearly equal size, the thumb being reduced to a vestige. In the hind foot the great toe has entirely disappeared and the little toe is found in a vestigial condition. Next came *Orohippus* of the Upper Pliocene, with the little finger reduced to small size; next *Mesohippus* of the Lower Miocene with the little finger reduced to a small splint bone; next *Protohippus* of the Lower Pliocene with three toes on both fore and hind feet. There was a whole series of three-toed horses showing varying degrees of reduction of second and fourth toes, with *Pliohippus* of the Upper Pliocene showing the lateral toes in the form of long, fairly bulky splint bones without hoofs. This series leads inevitably to the modern genus, *Equus*. Tooth specialization, neck and head changes, and steady increase in size run closely parallel with reduction in toes. The whole history is so clear and so complete as to constitute a demonstration that the modern horse has been derived from a small five-toed ancestor that lived about three or four millions of years ago. Although undoubtedly the horse pedigree is one of the most complete yet discovered, it does not stand as an isolated case, for there are many other pedigrees equally long and convincing.

The Fossil Pedigree of Man. There is nothing very unusual or exceptional about man's fossil record. While it is much less complete at present than that of the horse, the camel, the elephant, and other terrestrial animals, it is considerably more complete than that of the birds, the bats, and other types of flying animals. Much has been said about the fragmentary character of the human fossil pedigree but in this respect it is not unique. In fact there are records of many lower groups that are less complete.

One fact stands out above all others when we study human fossil remains, namely, that man has been a long time in the making. Beside the known antiquity of some human remains the six thousand years since creation of Bishop Ushur seem excessively recent. According to the most expert testimony available the oldest fossil in the human pedigree is about half a million years old, while the present species of man, *Homo sapiens,* is very conservatively estimated as more than 25,000 years old, while other species of true man date back over 100,000 years. Let us briefly review the most important stages in man's fossil history.

Pithecanthropus erectus. This species is the "Missing Link" of journalism, the Java Ape-man of science. The remains consist of a complete skull top, three teeth, and a left thigh bone. These were found scattered over twenty square yards of space and were not all found at once. While there is no proof that these fragments belonged to the same individual, there were no other skeletal parts in the neighborhood that they could be associated with. The point is that they are all much more human than anything else and that they come from a stratum not less than 500,000 years old. The calm and precise judgment of Gregory expresses the opinion of the anthropologists of today as to the significance of this little collection of fragments:

"The association of gibbon-like skull-top, modernized human femur and subhuman upper molars with reduced posterior moiety, if correctly assigned to one animal, may, perhaps, define *Pithecanthropus* as an early side branch of the Hominidæ, which had already been driven away from the center of dispersal in Central Asia, by pressure of higher races. But whatever its precise systematic and phylogenetic position, *Pithecanthropus,* or even its constituent parts, the skull-top, the femur, and the molars, severally and collectively testify to the close relationship of the late Tertiary anthropoids [apes] with the Pleistocene Hominidæ [man]."

Paleanthropus heidelbergensis. This is the genus known as the Heidelberg man. It is based on a single fragment, a complete lower jaw in a fine state of preservation with all teeth in place. It was found in a stratum whose age had already been determined to be about 400,000 years old. The jaw is very primitive and clumsily constructed as compared with that of any modern man. It lacks a chin as does the jaw of the gorilla. The teeth, however, are strictly human though larger than those of modern man. This combination of human teeth in an ape-like jaw serves as another link binding together man and the anthropoids.

Eoanthropus dawsoni. This genus has been called the Piltdown Man and is the oldest of the human remains found in England. The fossil consists of a skull, excavated by workmen and somewhat damaged before scientists got a chance at it. The reconstruction of this skull from the broken pieces has given rise to considerable controversy as to its original proportions, but some facts stand out beyond question. The skull shows a curious admixture of human and ape-like traits, the upper part of the skull being distinctly human, the jaw and teeth being even more simian than that of the Heidelberg Man.

Homo neanderthalensis. This is a well established species represented by many more or less complete skeletons taken from several localities of Europe. While these skeletons represent a race that was obviously human, they differ in many important ways from those of present-day man, necessitating classification as a different species. The neanderthals were of low stature, about five feet or a little more in the men and less in the women. The attitude was a stooping one with a very round back and no minor lumbar curvature. The head was large, long and flat, with ape-like brow ridges and an extremely receding forehead, and was supported by an immensely muscular neck in such a way as to thrust the face forward in simian fashion. The lower jaw was heavy like that of the Heidelberg Man and lacked a chin. The teeth were quite different in structure from those of present-day man, and are known as taurodont teeth, adapted for a very coarse vegetable diet. The brain was large and specialized in some parts, but deficient in those especially associated with the higher mental functions. There can be no doubt that *Homo neanderthalensis* is an extinct species of man, quite different from the modern species of *Homo sapiens.* The neanderthals died out about 50,000 years ago.

Homo rhodesiensis. This species of man is represented by a perfect skull and a nearly perfect lower jaw, the tibia, both ends of the femur, collar bone and parts of the scapula and pelvis. It was found in the Broken Hill mine in South Africa. Experts are not fully agreed about this the latest human fossil, but the juxtaposition of a relatively advanced skull with an extremely primitive jaw indicates a curious admixture of human and anthropoid characters.

Homo sapiens. The present species of man dates back at least 25,000 years. At that time there lived in the caves of Europe a remarkable race known as Cro-Magnons, which is said to have been the most perfect physically that the world has seen. They have been found about twenty perfect skeletons. These men were tall, strong, obviously intelligent and artistic. as judged by their carvings and paintings found in the caves. Our chief interest in this race is that it gives us some idea of the relative antiquity of our own species.

In conclusion, it may be said that while man's fossil pedigree is not yet particularly imposing, it is by no means to be ignored as evidence that man has been derived from lower Primates. Moreover, with the rapid development of technical knowledge, Anthropology promises to give us much more information about ancient man within the next few decades.

II. Evidences From Geographic Distribution

Paleontology deals with the distribution of species in time; geographic distribution deals with their distribution in space at any given time. A composite map of the geographic distribution of all known species would be the most intricate picture puzzle imaginable and it would be a monumental task to decipher it. How can we get a clue as to its solution? One clue suggested by the creationist is that each species, when created, was put in that particular environment best suited to it. Let us examine this theory. If there are similar environments in different parts of the world we should find similar species in them, but this is by no means the case. In climates practically identical in Africa and in South America the species found in the two regions are utterly different. Again, it has frequently been found that a species that is only fairly successful in its native environment thrives far better when transported to a distant part of the world. Witness the case of European rabbits carried to Australia, where they throve so abundantly as to become a pest. Again, call to mind the tremendous success of the English sparrow which finds America much more congenial than the British Isles. The first clue, then, is a failure.

If animals are not distributed so that each occupies the spot best suited to it, how then can we account for their distribution? Three main facts about organisms that are crucial for our theory are these: first, environments are changing and have changed frequently in the past—a fact ignored by the creationist; second, organisms have a fashion of migrating from one region to another and spreading out through multiplying their numbers and occupying more territory; third, barriers to a large extent limit the spread of one species and sometimes keep two neighboring species apart.

A study of the distribution of the species of a large genus is most instructive. As a rule, we find that the most primitive or generalized species (the type species) occupies the center of the territory covered by the genus, and the more specialized species occupy outlying areas adjacent to but more or less separated by barriers from the type species. Taking these and related facts into consideration, we are able to suggest as a clue to our puzzle the following hypothesis: A parent species gets a start in a given limited area, it multiplies and spreads out centrifugally in all possible directions, modifying as it goes in order to meet changed conditions or merely because one section becomes isolated by barriers from another. Such isolated groups, being unable to interbreed with the main body of the species, will not have a chance to participate in hereditary variations arising within the parent group, but will develop their own new characters independently and will in time become distinct species.

This clue when put to a test has served to clear up large sections of our picture puzzle. It is a most valuable aid in arriving at an understanding of the relationships of species and in explaining many mysteries that have no other known explanation. In other words, the evolutionary principle, when used as a working hypothesis, really rationalizes geographic distribution and makes a science of what was formerly a confused mass of data.

Of all the numerous phases of geographic distribution that might be chosen for illustrative purposes that furnished by the inhabitants of oceanic islands is probably the best.

The Inhabitants of Oceanic Islands. Oceanic islands are small isolated bodies of land of volcanic origin, far from continents. They are usually the tops of oceanic mountains or else coral atols built up about submerged craters. All such islands have their plant and animal populations, and these should furnish a crucial test of the validity of the rival theories of evolution and special creation. Both creationists and evolutionists agree that these islands have obtained their populations from continental bodies. If then the island species are identical with those of the continent from which they have been derived, it is obvious that no evolution can have taken place since they left the continent; if, however, they are different from any species now on the continent, the degree of difference between them and the most nearly similar forms on the continent should give us an accurate measure of the extent of evolutionary change involved. What are the facts?

Practically all species of animals on oceanic islands are types capable of transportation in the air during storms or in the water supported by floating débris. All species belong to those groups characteristic of the most available continent; but while in general they resemble the continental species, it is the rule to find that they are at least specifically distinct from them. The fact is that most island species are unique, that is, not found anywhere else in the world. They may belong to the same genus or family as do continental species, but often they belong to different genera or even different families. Such being the case, we have no alternative but to conclude that new species and even new genera have originated under island conditions.

The extreme case is that of the island of St. Helena, over a thousand miles from the coast of Africa. On this little body of land explorers found 129 species of beetles, all but one of which were unique. The species belong to 39 genera, of which 25 genera were unique. There were also 20 species of land snails, of which 17 were unique. Of 26 species of ferns 17 belong to unique genera. While St. Helena has more unique species than any other island, the same situation in less marked degree is presented by the Azores, Bermudas, Galapagos Islands, Sandwich Islands, and numerous others. The islands closer to the continents have fewer unique species because they receive more frequent immigrants that commingle with the native forms and tend to keep the island population in genetic contact with the continental population.

This meager sample of the way in which the facts of geographic distribution tend to demonstrate the validity of evolution must serve our present purpose. The evidence here cited closely approximates direct proof.

Summary of Evidences

All lines of evidence here presented strongly bear out the reasonableness of the evolutionary theory, and none are contrary to the theory. Moreover, most of the facts are utterly incompatible with the special creation idea. Not only do these evidences tell a straightforward story of evolution, but each one is entirely consistent with all the others, and each line of evidence aids in understanding the others. Thus embryology greatly illuminates comparative anatomy and classification; geographic distribution is aided by and aids paleontology; blood tests and classification mutually support each other. The principle of evolution is then a great unifying and integrating scientific conception. Any principle so far-reaching, so consistent, and so useful in forwarding the progress of scientific discovery, is at least worthy of our highest respect and should by all means receive the support of every thinking person. It should not be lightly cast aside without careful examination simply because it fails to agree with the doctrines of medieval theology.

CHAPTER VII

INTRODUCTION TO GENETICS

Facts versus Theories. The brief survey of the evidences just given should convince the reader that the principle of evolution is well founded. One can readily convince himself as to how thoroughly established the theory is only by making an adequate study of the evidences. All who have done this are convinced that the principle is proven. The professional biologist has long ceased to question the *fact* of evolution and has concerned himself with the problem of its *causes.* We know a good deal about the course evolution has followed in large numbers of groups of animals and plants. In some cases we know in detail what steps have been taken in passing from one type to another, but we are still unable to say just what is the motive power of evolutionary change or what are the factors controlling the direction of evolution.

There is a great difference between knowing that evolution has occurred and explaining the workings of the factors responsible for the changes we know to have occurred. It is in connection with theories as to the causes of evolution that we find so much uncertainty and difference of opinion. Biologists admit their inability to give final explanations for some of the observed facts. This doubt about the exact mechanism of evolution does not, however, reflect upon the validity of the principle.

An instructive parallel will serve to make this point clearer. With the aid of microscopes and histological technique it is possible to study the development of an individual from a single cell. We can see the cell divide and observe the workings of an intricate little machine known as the mitotic mechanism, meticulously dividing up the characteristic materials of the cells in such a way as to leave each daughter cell half of everything present in the mother cell. We can see without difficulty the beginnings of the formation of tissues and organs and can in many cases trace definite cells to definite tissues. In brief, we have no difficulty in describing in detail every event in the evolution of an adult individual from a single microscopic cell. The facts of embryology are unquestioned, but, strangely enough, we know precious little about the actual causes of individual development. Just what is the motive power that makes a cell grow and divide; just what makes one kind of cell develop into an individual of one species and another kind of cell, very like the first, into an individual of a very different species; just why an individual stops developing where it does; just how the various tissues collaborate to form an intricate structure such as the eye; these, and many other problems are at present largely unsolved. Various theories have been suggested but none are adequate.

Because we are unable to explain the causo-mechanics of the development of an individual, we do not doubt the plain facts of such development. No more then should we lose our faith in the plain facts of racial evolution because many of the explanatory causo-mechanical theories are still unsatisfactory. If it is difficult to explain individual development, how much more difficult will we be prepared to find the problems of racial evolution!

What Genetics Is

"Genetics," says W. E. Castle, "may be defined as the science which deals with the *coming into being* of organisms. It does not refer, however, to the first creation of organic beings, but rather to the present every-day creation of new individuals or new races. It refers particularly to the part that parent organisms have in bringing new organisms into being and to the influence which parents exert on the characteristics of their offspring."

While older methods of evolution consisted largely of collecting facts about evolutionary events that have already taken place long ago, Genetics has developed a new method: that of watching for changes and when they occur controlling their perpetuation by carefully designed breeding experiments. Thus Genetics is fundamentally experimental in method. The idea is to get control of evolutionary processes with the hope that when we learn to manage them to our satisfaction, we shall then know what makes them go. Genetics has a still more ambitious aim, namely, to produce evolutionary events by the use of new or unusual agents. As yet we have not been very successful as creators of new characters, but we have gone far in the production of new types by combining old characters in all sorts of new ways, so that the types produced are almost as worthy the name of creations as actual new characters would be. Even if we have not yet learned how to make new characters we have observed the origin of thousands of them. We are at present directors of evolutionary change, but we cannot yet claim to be creators.

The Principal Causal Factors of Evolution

Some positive statements about the causes of evolution may be made without fear of successful contradiction. We are now quite certain that the two primary factors in evolutionary change are

Variation and *Heredity.* *Variation* is the creative factor, and includes all agents responsible for producing change. The production of new hereditary characters (mutations), the modification of structures in response to function or to environment, the production of new combinations of old characters; all these come under the head of variations. Mutations and combinations have much to do with evolution because these variations are hereditary and effect more than one generation; modifications may or may not effect the course of racial evolution, and there is a rather strong consensus of expert opinion that they do not effect any generation beyond that in which they occur. Variation alone could give no evolutionary progress but would merely mean that each generation would be different from the previous one. Unless variations occurring in one generation are passed on to future generations no evolution would be possible.

Heredity is the conserving or perpetuating factor. It passes on to descendants the hereditary variations of the parents. The passing on of variations is by no means simple, for there is an intricate shuffling and redealing of the characters of the two parents. Yet even this progress is carried out with such regularity that it is capable of being reduced to certain definite formulæ, known as the Laws of Mendelian Inheritance. Heredity alone would give us the kind of world the creationist believes in, one in which there is no variation but merely a continuation of the same types forever. Variation alone would give nothing but chaos. But a combination of variation and heredity furnishes the main factors necessary for evolution. With new characters constantly occurring and many of these transmitted to progeny there could be nothing else but continuous evolutionary progress.

Selection, Isolation, and *Orthogenesis* are thought to be secondary factors, having to do respectively with the perfection of adaptiveness or fitness in organisms, with the establishment of new species, and with maintaining the definite course of organic change. These three factors will be discussed in Chapters XI and XII and need not concern us further here. Our first purpose is to study the primary factors of evolution—variation and heredity—and we shall devote a chapter to each.

CHAPTER VIII

THE PHYSICAL BASIS OF HEREDITY AND OF VARIATION

I. The Mechanism of Heredity

Every individual belonging to one of the higher groups of animals starts its life from a single cell, a fertilized egg cell. Such a cell not only produces a new individual: it is a new individual. Each fertilized egg cell (technically a *zygote*) is a unique individual with certain definitely determined potentialities, some of which have been contributed by the egg cell (the cell derived from the mother) and others by the sperm cell (the cell derived from the father). No two zygotes get exactly the same combination of paternal and maternal characters, and that is why no two offspring are alike even when derived from the same parents. This very simple fact, that offspring are never just like parents or alike among themselves, is one of the principal reasons why evolution occurs, for there is no possibility, with such a variety of individuals, of the species remaining unchanged from age to age.

Cells such as eggs, sperms, zygotes, are collectively known as *germ cells,* because they are the *"germs"* of new individuals. One thing about germ cells is obvious: that they must carry the potentialities of the adult individual within their microscopic bodies. A zygote certainly carries within it the potentialities of all the peculiarities that appear in the adult. There are, of course, no eyes, no legs, no heart, no brain, in a zygote, but there is something in the zygote that has in it the special ability to produce eyes of a particular shape and color, legs of a particular length and form, a heart strong or weak and with a characteristic rhythm, a brain with particular powers and idiosyncrasies.

One of our great problems, which is only partially solved, is that of locating in the zygote those structures which carry the potentialities of determining the peculiarities of the adult that lie latent in the single cell.

The Structure of a Cell

When we describe a cell we do not claim to give an exact account of any particular kind of cell, but merely of a typical cell that may be taken as a pattern for cells in general, including germ cells.

As a rule, a cell when not crowded by neighboring cells is more or less spherical. On the outside of such a cell there is a *cell membrane* which serves as a protection and presides over the various nutritive exchanges between the living protoplasm within the cell and the materials of the environment. Near the center of the cell is another body surrounded by a membrane, known as the *nucleus*. Between the nucleus and the cell membrane is the *cytosome*, a zone of living substance more or less complex in make-up, for it contains many kinds of materials, including such components as yolk granules, plastids, vacuoles and numerous other structures. Each kind of cell in the body of an individual differs primarily from other kinds of cells in the form and content of the cytosome. The nucleus is essentially the same in all cells of a given individual. Thus, the cytosome of a liver cell, that of a skin cell, that of a muscle cell, that of a nerve cell and that of an egg cell are very different, but the nucleus is practically the same in all of these.

The Chromosome Theory of Heredity

The nucleus is known to be, more than any other part of the cell, the organ of heredity. It contains a material known as *chromatin*, which is not found elsewhere in the cell and which is known as the bearer of hereditary differences. This chromatin, while ordinarily scattered about in the form of fine granules strung on so-called *linin fibres*, aggregates at times into definite minute lumps or bodies known as *chromosomes*. Each species of animal has a definite number of chromosomes, ranging in various species from two to nearly a hundred. Not only are the numbers of chromosomes constant for a given species, but the shapes and sizes of chromosomes in a given species frequently differ to such an extent that it is possible to recognize particular chromosomes and to tell one kind from another.

It is now known that each kind of chromosome in a zygote is present in duplicate, and this becomes evident when they come together in pairs during *synapsis,* a process to be spoken of later. The significance of the double set of chromosomes is merely this, that each parent has contributed one complete set. For the present, let us merely use this fact as part of the evidence—and there is abundant evidence from other sources—that each pair of chromosomes is different from the others in the kinds of hereditary potentialities carried. Each kind of chromosome carries a unique set of determiners (technically known as *genes*), and the lack of a particular gene may make it impossible for a complete individual to develop. This being the case, it is of the utmost moment that the integrity of the chromosomes, or at least of all the genes, be preserved and passed on from generation to generation. There is in the cell a beautiful little mechanism especially adapted to do just that thing, namely, the *mitotic mechanism,* already referred to in another connection.

Mitotic Cell Division

When a zygote starts to develop into an adult individual the first step it takes is to divide into two cells like itself. It does not roughly break apart into two halves, but the halving of the cell is done with the greatest precision so as to bring about an equal division of all ingredients necessary to produce an individual.

We are here particularly interested in the way in which the mitotic machine handles the chromosomes, for these are the elements with which heredity is especially associated. The early stages of mitosis involve the development of the division machine, the *mitotic spindle,* a beautifully balanced bipolar figure composed of fibers. This figure arises afresh at each cell division and we are not sure just where its materials come from, but they appear to be due to an interaction between nucleus and cytosome. Suffice it to say that the mitotic figure arranges itself with one pole toward one side of the cell and the other toward the opposite side. While this mechanism has been forming, the chromosomes have drifted to the center of the spindle of fibres and have arranged themselves in such a way as to be exactly in equilibrium between the two poles. Then each chromosome splits from end to end into twin halves, one half being then drawn to one pole of the spindle, and the other half to the opposite pole. Finally, the cytosome constricts across the equator of the spindle, the two groups of chromosomes become two nuclei, and two complete daughter cells are formed. This is the essential act of heredity as well as the fundamental act of reproduction. In this act of mitotic cell division we see how continuity of substance may be maintained; for the rest of development consists of repetitions of this act until millions of cells are formed. Some cells become different from others in their cytosomes, but the nucleus remains essentially identical in all the cells of the body. The variety of shape, size and structure of body cells is largely due to a differentiation of the cytosome through differences in function of the cells and differences in position with reference one to another. But this is a difficult problem of embryology and does not especially concern us in our present attempt to understand heredity.

How Germ Cells Are Produced

We have seen how the organism takes care of and treasures the hereditary substance given to it by its parents. Every cell should, according to our thesis, contain all the necessary ingredients to form a new individual. In some of the lowest organisms almost any cell, or a few cells from any part of the body, if cut off from the parent, may produce a new individual; but in higher organisms only certain cells of the body (germ cells) retain this power of reproduction. All other cells seem to lose their powers of reproducing whole individuals when they specialize very extensively for particular functions. The germ cells are essentially cells that have retained their embryonic or undifferentiated character till other tissues have practically completed their specialization. These primitive cells then specialize as follows: the egg cells become large and passive, storing up food for the young individual to use in growth, while the sperm cells remain very small, having no stored food, but develop locomotor organs useful in making journeys to find the egg. In the end stages of their course of specialization both egg and sperm are specialized cells, but during the life of the parent these cells have not specialized in other ways.

The Continuity of the Germ Plasm

Each germ cell may thus be conceived of as a lineal descendant from the zygote through a continuous series of germ cells that have never been specialized parts of the parent body, but have merely been housed by the body tissues. It is a mistake to suppose that the parent body makes the germ cells, for germ cells are not descendants of body cells but come only from germ cells. Thus there is an unbroken continuity of germ cells from generation to generation. This concept is known as Weismann's principle of the *Continuity of the Germ Plasm* and is one of the foundation stones of modern Genetics. With the mitotic mechanism to attend to the preservation of the integrity of hereditary substance and the continuity of the germ plasm to mark out the path and constitute the bridge from generation to generation, we can readily understand why there is a high degree of constancy of types or species for long periods. Now that we have discussed the heredity machine, which by itself would give constancy of type, let us look at the other side of the process of evolution, the variation mechanism.

II. The Mechanism of Variation

Maturation of the Germ Cells. The almost infinite diversity that exists among individuals of the same species is attributable largely to a peculiar sort of shuffling and dealing of the chromosomes and the hereditary materials carried by them. Perhaps the most distinctive peculiarity of germ cells, as opposed to body cells, is that they go through a well-defined routine known as the *maturation divisions.* Just before the male and female germ cells reach their final stages of maturity there occurs in the nucleus a significant event, namely, the chromosomes unite in pairs and only those representing equivalent genes pair off. This is known as *synapsis.* Then the same mitotic mechanism, ordinarily used as a hereditary machine, plays quite a different rôle, that of a variation machine. The pairs of chromosomes drift to the equator of the spindle and arrange themselves with one chromosome of each pair toward each pole. When cell division occurs one chromosome of each pair goes to each pole and two germ cells are formed. Each is in a sense a half cell for it has only one chromosome of each kind, or half the number characteristic of the species. This is called the *haploid* condition and the cells with the single set of chromosomes are known as *gametes.*

Now let us remember that the paired chromosomes represent the maternal and paternal contribution of the parents. That means that when gametes are produced no gamete can have both maternal and paternal hereditary units of a given kind but can have only one or the other. Each of the paired chromosomes behaves as though entirely independent of all the rest, so that an individual gamete has an even chance of getting the maternal or the paternal component of each pair of chromosomes. The number of different assortments of maternal and paternal chromosomes is very large. Suppose a species has only eight chromosomes represented by ABCD and abcd, the large letters representing the maternal and the small letters the paternal chromosomes. A and a, B and b, C and c, D and d pair in synapsis. In the reduction division there are possible sixteen different kinds of gametes, namely, ABCD, aBCD, AbCD, ABcD, ABCd, ABcd, AbCd, aBcD, aBCd, AbcD, abCD, abcD, abCd, aBcd, Abcd, abcd. There will thus be sixteen possible different assortments of maternal and paternal chromosomes in the female gametes (eggs) and the same number in the male gametes (sperms).

Fertilization. When eggs are fertilized by sperms there is an equal chance of each of the sixteen kinds of eggs uniting with each of the sixteen kinds of sperms and there will therefore be sixteen times sixteen (256) different kinds of fertilized eggs or zygotes produced, each of which will have again the double (*diploid*) set of eight chromosomes characteristic of the species. When the numbers of chromosomes run up into such numbers as 48 (that characteristic of man), the number of possible combinations becomes almost unbelievably high. In fact it runs up into the millions. A calculation shows about 16 million possible kinds of gametes and about 256 millions of possible zygotes, all different. Is it any wonder then that no two members of a given family of children are alike, for there is only one chance in 256 million of their being identical in their heredity—unless, like duplicate twins, they are the product of the division of a single zygote?

Crossing-over. In addition to the wide range of diversity produced by the mechanism of maturation, there is still another means of increasing variability. When the paired chromosomes are lying in contact prior to the reduction divisions they nearly always exchange equivalent sections of genes with each other and the exchange may take place at any part of the chromosome. Thus when chromosomes separate in the reduction process they are mixed chromosomes, partly maternal and partly paternal, and the number of different admixtures possible within a given chromosome is very large. This so-called *crossing-over* of genes from one to another of homologous chromosomes has been discovered by an elaborate analysis of ratios in which different genes are associated in individuals, an analysis that cannot readily be explained in this little book. Suffice it to say that the working out of this concept represents a high point in modern genetic analysis.

Now that we have some acquaintance with germ cells and chromosomes and their routine behaviors, let us study some of the products of the machine, namely, the laws of heredity that are dependent upon the processes just described.

CHAPTER IX

The Laws of Heredity

Gregor Johann Mendel, an Austrian priest born in 1822, is credited with the discovery of the essential facts about heredity, and his discoveries have been called Mendel's Laws of Heredity. Although Mendel undoubtedly discovered the fundamental laws of heredity he had no conception of the practically universal application of his results. We cannot do better than to begin with a study of some of the laws which he stated and some of the modern explanations of these laws.

I. The Law of Independent Unit Characters. Mendel was among the first to recognize that heredity has to do with characters and not with the whole organism. An individual is a bundle of more or less independent characters. Thus an offspring may have the eyes of his mother, the stature of his father, the temperament of his grandfather and the musical ability of his grandmother.

II. The Law of Allelomorphs. When two different individuals mate they bring together certain pairs of mutually exclusive characters. Thus one parent may have brown eyes, the other blue; one may be tall, the other short; one may have dark skin, the other fair; one may have musical ability, the other none; one may have immunity to a particular disease, the other susceptibility. These opposed characters, or at least the genes in the germ cell that stand for them, are known as *allelomorphs.*

III. The Law of Dominance. When two individuals differing in but one pair of allelomorphs mate, their offspring will exhibit either one, but not both, of the opposed characters. The one that appears to the exclusion of the other is known as the *dominant* character, and the one that fails to appear is the *recessive* character. This law is best illustrated by an experiment in *hybridization*—and this was Mendel's method. If two distinct races of animals or plants are crossed, it is simpler to follow the laws of heredity because they have more sharply contrasting unit character differences than do members of the same race. But let us not forget that the same laws also apply whenever individuals of the same race differ in unit characters. When we pay attention to the modes of heredity of but one pair of allelomorphs at a time, we call it a *Monohybrid Experiment.*

For example, we may cross a black guinea-pig with a white one. All the offspring of such a mating will be black, for black is dominant. Similarly, short hair is dominant over long hair, and rough or rosetted hair is dominant over smooth hair. The explanation of dominance is that the dominant character is due to the presence of some gene that is absent in the recessive individual. This is known as the *Presence and Absence Hypothesis,* and is generally accepted as valid.

IV. The Law of the Splitting of Hybrids. Let us follow up the guinea-pig experiment for another generation by interbreeding the first generation hybrids (the F_1 generation, as it is now universally called). The result in the second generation, if sufficiently large numbers of offspring are produced, will be that three out of every four individuals will be black and one white. The F_1 black hybrids have split up in their offspring into blacks and whites in the ratio of 3: 1. The same ratio will result from any other experiment, whether with animals or plants, so long as we are dealing with but one pair of allelomorphs. This is a strikingly regular result and suggests a mechanism of extraordinary constancy. We have already in the last chapter described this mechanism when dealing with the behavior of the chromosomes in the formation of gametes and in the union of gametes to form zygotes. Thus each F_1 hybrid gets a black-bearing chromosome from one parent and a white-bearing chromosome from the other. Each hybrid has in its unreduced germ-cells both black and white, but black is all that appears in their bodies. When these F_1 hybrids become sexually mature, their germ cells undergo maturation and gametes are formed, but the gametes are pure for either black or white, since they can have only one or the other of paired chromosomes. Each F_1 parent will have as many black gametes as white, and a chance union of gametes will give the following result, if we allow B to stand for black and w for white:

$$\begin{tikzcd}
\text{Eggs} & \text{Sperms} \\
B \arrow[r, leftrightarrow] \arrow[dr, leftrightarrow, dashed] & B \arrow[dl, leftrightarrow, dashed] \\
w \arrow[r, leftrightarrow] & w
\end{tikzcd}$$

Once out of four times a B gamete will unite with another B gamete; once out of four times a w gamete will unite with a w gamete; and twice out of four times a B gamete will unite with a w gamete. Since every individual with B present will be black, it is clear that in the F_2 generation that we will have 3 blacks to 1 white. In this case two doses of black give a more complete black coat than one dose, so we are able to distinguish between the BB individuals and the Bw ones.

The chromosomal mechanism is thus seen to be adequate to explain the Mendelian ratios and the law of the *Purity of the Gametes.*

In the third (F_3) generation *BB* individual interbred give nothing but pure black offspring; ww individuals interbred give all pure white offspring; but the Bw individuals (as in F_2 matings) give 3 blacks and 1 white.

Substitute *S* (short hair) for *B* and *l* (long hair) for *w;* or substitute *R* (rough hair) for *B* and *s* (smooth hair) for *w;* or, in fact, let any dominant (*D*) be substituted for *B* and any recessive (*r*) be substituted for *w,* and we will have a universal formula for the ratios of heredity in the F_2 generation. Such a universal formula would be $1DD + 2Dr + 1rr$. This is the *Monohybrid Mendelian Ratio.*

Each pair of allelomorphs behaves in this way and quite independently of how other pairs of allelomorphs behave. We can readily see then that all sorts of combinations of dominant and recessive characters will come to lie in the numerous gametes and zygotes.

V. The Factor Hypothesis. This concept is relatively new and has not yet been promoted to the rank of a law. It is, however, the most important of the discoveries in heredity since Mendel's work. According to this hypothesis characters are very commonly not "unit characters" in the sense of Mendel, but are due to the interaction of two or more pairs of genes or *factors*. Thus, when we breed together a red-flowered plant (say Four-o'clock) with a white-flowered plant, we get in the F_1 generation no reds or whites, but pinks. Interbreeding the F_1 pinks gives 1 red, 2 pinks, and 1 white. Evidently then red is due to two factors (genes) and pink to one factor for red. Again, when we breed together two kinds of corn, one red-grained and another white-grained, nothing but red-grained corn appears in the F_1 generation, but in the F_2 generation there appear 9 reds and 7 whites. This is not the expected ratio of 3 dominant to 1 recessive, but something entirely different. What does this mean? The explanation that is now considered adequate is that red color is due to two factors neither of which alone has any effect. The two factors are thus complementary and are carried in different chromosomes. The two factors may be called R (red pigment factor) and C (a complementary factor necessary for the appearance of red pigment). Each of these will have an allelomorph in the homologous chromosome. The F_1 hybrids will have all four kinds of chromosomes which we may call R and r, C and c. When gametes are formed there will be four kinds: RC, Rc, rC, and rc. These will be present in equal numbers in both eggs and sperms, so that when fertilization occurs the following kinds of zygotes will be formed in equal numbers: RCRC, RCRc, RcRC, RCrC, rCRC, RcRc, RcrC, rCRc, RCrc, rcRC, rCrC, rcRc, Rcrc, rcrC, rCrc, rcrc. It is easy enough to count nine zygotes with both R and C present and seven zygotes lacking either R or C or both. In this way we have accounted for the ratio of 9 reds to 7 whites.

Inhibitory factors are known to exist which prevent the action of other factors. *Supplementary factors* when added to a dissimilar factor result in a character modified in some way.

VI. Inheritance of Quantitative Characters. For some time after the discovery of the laws just discussed it was commonly believed that mere quantitative differences were inherited in a blending fashion, that is, that the offspring struck an average between the two parents. Thus, lop-eared rabbits bred with rabbits of the ordinary ear length gave "half-lops," while "half-lops" bred with normals give "quarter-lops." This type of hereditary is now explained as a case of Mendelian heredity involving the new idea that there may be two or more factors having identical effects but inherited separately because carried in different chromosomes. According to this view lop ears contain four more factors for length than ordinary ears. Hybrids between "lops" and ordinary rabbits give "half-lop" ears with two factors. These bred with ordinary rabbits give "quarter-lops" with one factor. "Three-quarter lops" are the result of interbreeding a "full-lop" with a "half-lop." Many other examples of this kind of heredity have been worked out, notably, the inheritance of skin color in negro-white crosses, and the inheritance of color in kernels of wheat.

With the introduction of the factor hypothesis we stepped from elementary Genetics into advanced Genetics. It is not feasible to carry the reader, who merely wishes a knowledge of the broad outlines of evolutionary Biology, any further into the ramifications of this remarkable science. Genetics today is an intricate and technical branch of Biology and is adequately understood only by the experts. These men who are delving into the inmost secrets of the germ cell and its workings are the hope of the future in evolution. From them will come, and in the next few decades, the solution of causal problems many of which seem almost unapproachable today. Much as we should like to give our readers some conception of the recent advances of modern Genetics, we realize that it would be impossible to do so without entering upon some of those phases of the subject that require extensive study and a technical vocabulary.

Summary of Laws of Heredity. Some of the points to bear in mind at this juncture are: *a*, that the real units of heredity are the factors (called "genes" by one school of geneticists); *b,* that, whether the gene is dominant or recessive, it finds its way into a fixed ratio of the gametes and is certain to give evidence of its presence in a definite proportion of the offspring; *c,* that the interplay of several, or perhaps of all factors, is involved in the production of a character; *d,* that if genes or factors are the real units of heredity we may well expect evolutionary changes to take place by the addition of new genes, the loss of old ones, or the modification of those already in existence.

CHAPTER X

THE MUTATION THEORY

In the last chapter we called attention to the fact that the materials with which heredity deals are the units known as factors or genes. We have seen that various combinations of these ultimate units of heredity give rise to the character differences that distinguish individuals, races, species. In hybridization experiments we are concerned merely with a study of the shuffling and dealing of these genes into different packs (the gametes), by means of the reduction process. And then double packs (zygotes) are formed by the fertilization of eggs by sperms. The whole thing is like an intricate game of cards in which the cards are all supplied at the beginning. An almost endless variety of combinations can be made and frequently characters are so modified through the chance union of genes from different parents that they seem like new characters. The production of such combinations is, however, not permanent, for in the next generation any particular combination of genes is sure to be broken up and other combinations formed. The point we wish to make is that no new genes are introduced, lost, or altered in this whole process of Mendelian assortment and recombination.

Gene Mutations

Genes are relatively constant units and change only at rare intervals, but the important fact is that *they do change* once in a while and quite suddenly. After changing, the new gene is likely to be as constant as the old. As has already been pointed out the gene change is the real primary creative act and is most important as a contribution to evolution. Let us examine some few of the best known examples of mutations. Professor Morgan and an able corps of collaborators have made an intensive study of mutations in the fruit fly *Drosophila,* a species chosen because of the rapidity with which it breeds and the ease with which young may be reared. In the course of nearly a score of years many millions of flies have been reared under rigid observation and all hereditary changes have been recorded. No less than two hundred different gene changes (mutations) have occurred in this time and the same mutations have occasionally repeated themselves. These gene changes have affected practically every organ or structure of the body. Among the commonest mutations are changes in color or in shape of the eyes, in body color, in wing size and shape, in size and shape of bristles, in form of legs, and in general health or viability. Perhaps the most frequent of all mutations are the so-called lethal mutations which when present in the homozygous condition (*i.e.,* when contributed by both parents) causes death at some time during development. Lethal factors are inherited just as are other genes and are discovered when double recessives fail to appear in the F_2 generation. The great majority (over 90 percent.) of the mutations observed in Drosophila are changes for the worse and it is doubtful whether a single observed mutation in this species is really better than the normal character whose place it takes. Nevertheless, it is likely that a few of the new characters are as good as the old, and if the environment were to change in any marked degree, some of these mutations might readily fit into the changed conditions better than the so-called normal characters. We should not be led to look askance at the whole mutation idea because so few mutations seem to be in the nature of real improvements, for let us remember that the particular set of characters now normal to a species represents the best mutations accumulated by the species during millions of years. These characters are tried and tested and have proved their value. Why then should we expect them to be ousted by every upstart mutation that comes along?

Moreover, knowing the extraordinary slowness of evolutionary progress, we should expect a real improvement only at very rare intervals. Whether, however, a new mutation is an improvement or not, it is sure to persist in some individuals of the species unless the change be so harmful that it militates seriously against the success of the individual or the possibility of producing offspring. Many entirely neutral mutations (neither advantageous nor disadvantageous) have been observed, and these may well be the units that serve to differentiate species, for species differences are frequently rather superficial and, so far as we can tell, non-adaptive.

Mutations in Man. In our studies of human heredity we are handicapped by our inability to conduct the work by the methods of the experimental breeder. In spite of this obvious disadvantage we are able, by the study of family histories and pedigrees, to ascertain that gene mutations occur at rare intervals in man. Some of the human characters that may be safely classed as mutations are, brachdactylism (a dominant character in which the fingers are all like the thumb), polydactylism (supernumerary fingers and toes—also dominant), certain kinds of cataract, color blindness, free-bleeding, dwarfism, giantism, some forms of insanity, feeble-mindedness, some forms of genius, and a long list of minor peculiarities that we shall not take space for here. As in Drosophila, the majority of these changes, whether dominant or recessive, appear to be changes for the worse, but who knows whether under different conditions some of these human mutations might not prove to be adaptive? If various types of genius are to be considered as racial assets, we may thank the mutation process for contributing at least some of them.

Mutations in Domestic Animals and Plants. There is no doubt but that many, if not most, of the real novelties among our stocks and crops are due to mutations. Certainly albino races, melanic (black) races, hornless races, curly-haired races, long-haired races, dwarf races, various fancy double races of flowers, disease resistent races of grains; these and hundreds of other well-known varieties have been the result of seizing upon mutations and perpetuating them by selective breeding. The mutational novelties, however, must be carefully distinguished from those produced by hybridization followed by vegetative propagation—the method followed by Burbank and many others.

Causes of Mutations. When we come to discuss the causes of gene mutations we are forced to admit that we are almost entirely in the dark. By the use of alcohol, X-rays, and other agents investigators have been able to induce changes in the germ cells of such a kind that the individuals arising from such germ cells exhibit variations not unlike those that occur spontaneously in nature. Defective eyes, feet, and skin have been induced by alcohol, X-rays, and other agents in rats, guinea-pigs and rabbits, and many of these changes are passed on to at least three, four or more generations of offspring. As a rule, however, these changes do not follow a strict Mendelian ratio, as do true mutations, nor do they continue to reappear beyond a limited number of generations, for the defects become progressively worse and finally kill off all those affected, thus bringing the mutant strain to an end. Most authorities are inclined to consider these more or less temporary germinal changes as distinct from mutations and to give them the name "inductions."

The only clue as to the causes of gene changes that we have is that we know from an analysis too intricate to offer here that any gene change involves an extremely definite locality of a particular chromosome, a locality, so minute that it cannot be much larger than a small aggregation of colloidal particles. It is now believed that a gene change is the result of a slight rearrangement of atoms composing the extremely complex molecules of the *chromatin,* a protein substance that makes up the chromosomes. Apart from this we know nothing about the causes of gene mutations, but there is another kind of germinal change about which we have more definite information.

Chromosomal Aberrations

While gene mutations seem to be the prevailing type of genetic changes in animals, there is another type of mutation that is prevalent in plants. This is the type originally called mutations by Hugo de Vries, the author of the Mutation Theory.

De Vries found in a species of Evening Primrose (*Oenothera larmarckiana*) a considerable number of specimens quite unlike the typical forms. These he found bred true to the changed condition. When he planted the seeds of the most typical specimens in the Botanical Garden of Amsterdam, he found that every year for eight years considerable numbers of changed types (mutants or elementary species) appeared. Many of these were inferior, sickly plants, but there were several extremely robust and vigorous mutants, especially a form known as *Oenothera gigas* (the giant) and *Oenothera rubrinervis* (the red-veined mutant). These were even better plants than the parent species. On examination of the germ cells of these two robust mutants it was found that *gigas* had twice as many chromosomes (28) as the parent species, which has 14; while *rubrinervis* has 21, one and a half times that of the parent. Most of the other mutants had 15 chromosomes, or one more than normal. Here we see that character changes of a very positive and definite sort are due to the addition of whole chromosomes, but as yet we have no definite explanation as to the cause of these chromosomal aberrations. It has been suggested that in the case of *gigas* that there was a failure to reduce to the haploid number in both egg and sperm and that in *rubrinervis,* only one of the gametes failed to reduce. The one extra chromosome is apparently due to a failure of paired chromosomes to separate in reduction, which causes both members of a pair to go to one gamete and leaves the other gamete without one kind of chromosomes. As yet we have no notion as to what causes these slips in the regularity of the reduction mechanism, but the effects are very striking in their somatic expression.

Many geneticists of the present time have found cases parallel to that described by de Vries. Blakeslee has made a very detailed and exact study of mutations in the Jimson weed, and similar studies have been made on roses, chrysanthemums and many other plants. In fact it appears that most plants exhibit this type of germinal change.

It should be emphasized that, although gene changes and chromosomal aberrations have both been classed as mutations, they involve entirely different processes. Both are important modes of genetic change and therefore fundamental for any clear understanding of the methods of evolution.

In conclusion, let us once more say that as evidence that evolution is taking place today nothing could be any more direct than the studies of mutations. Real genetic changes, sometimes so pronounced that in one step an extremely novel type is produced, sometimes so minute as to escape the notice of any but the eye practised in the discovery of organic minutiæ, can be observed in any species that is made the object of intensive, systematic study. These changes, both large and small, are hereditary and reappear in Mendelian ratios in successive generations of offspring. All such mutations are passed on as either dominants or recessives unless they are so detrimental in their effects as to impose an undue burden upon their possessors. Thus there is a survival of the fit mutations and an elimination of only the unfit.

If evolution means organic change capable of being passed on by heredity, then, in mutations, we can actually observe evolution taking place. This is direct proof of the validity of the evolution principle.

CHAPTER XI

THE PROBLEM OF FITNESS

Everyone is impressed by the apparent purposefulness of nature. A human eye seems designed to act as an optical instrument; a bird's wing seems admirably adapted to act as an aerial plane and propeller combined; the various types of fore limbs of vertebrates, arms of man, flippers of the whale, feet of the horse, wings of the bat, all seem to be especially adapted for a particular use; the reduction division and the fertilization process seem to be exactly intended to act as the machine of variation; the instinct of bird and of spider in building nests and snares, the instinct of the ant in caring for young and building elaborate galleries; these and many other examples of fitness or adaptation readily come to mind.

But lest we gain too profound an admiration of the fitness of organic nature, let us cite a few examples of unfitness. Think of the numerous useless vestiges in the body of man, such as the vermiform appendix, the ear muscles, the wisdom teeth, the disappearing gill pouches, the tail at first proportionately large and later reduced to a useless rudiment, the useless breasts of males, and numerous other relatively inefficient organs. Think of the vestigial hind limbs of whales, the complete set of teeth in sperm whales that never erupt and are never used, and the numerous human vestigial structures already described. Think of the beautiful colors and patterns of night-flying moths whose beauties cannot be seen when most displayed; of the wonderful exhibition of color on the inside of the abalone shell that never sees the light till the animal is dead; and finally, of the instincts of many animals that lead to their death, as the attraction of the moth for the flame and the instinct of man to make war. These are only random examples of unfitness, but the biologist of the present day sees so much unfitness in nature that he has revolted against the earlier cult of adaptation worship and is somewhat inclined to refer to the subject as "the great adaptation fallacy."

A saner position is one that admits the existence of many wonderfully adapted structures in organisms today, but also sees that adaptation is never even approximately perfect; that there is about as much unfitness in animals and plants as there is fitness; that general fitness in surviving species is inevitable, for in order to live in a particular environment an organism must initially be at least reasonably adapted to it and must progressively adapt itself during its development. Where then lies the mystery about adaptation?

Our chief problem is to explain the origin of certain adaptive structures and functions that seem to appear as though in anticipation of a need and are essentially perfect even before they are used. Instance the human eye, which is a finished product when the child is first born, though never used as an optical instrument during the prenatal period. The human lungs are never used for respiration or voice production until the child gives its first cry. The mammary glands of man and other mammals are perfected without previous functioning so as to be efficient at the first demand upon them. The nest building instinct of the bird and the web-spinning instinct of the spider are ready for their first use. These and thousands of other innate or hereditary adaptations offer a difficult problem that has never been satisfactorily solved. The creationist says that they were created at the beginning in order to subserve a useful purpose. But what about the useless or positively harmful structures and functions? Were they also created for a purpose?

Two main theories have been offered to explain the origin of adaptive structures, namely, Lamarck's theory of the Inheritance of Acquired Characters and Darwin's theory of Natural Selection.

These two theories commonly known as Lamarckism and Darwinism will now be discussed.

Lamarckism

One of the most extensively discussed questions in biology, and one about which there is still no definite conclusion, is the problem of the Inheritance of Acquired Characters. Lamarck's theory was that the *body* of an organism, through use or disuse of organs or through response to changing environment, becomes modified in appropriate fashion so as better to perform that function or to become better adjusted to the environment; that in some manner the changes in the body register themselves upon the *germ cells* so that the determiners (or genes) of the somatic characters will be more or less modified in appropriate ways; and that, by successive inheritance of such improvements for generations, the various organs become greatly improved through use, reduced to vestiges through disuse, or more perfectly adapted to special features of the environment.

This theory is to the layman so clear and logical that there seems to be no escape from it. How could the whale lose his hind limbs unless as the result of the inherited effects of disuse? How could the giraffe get his long neck except through the inheritance of the effects of generations of neck stretching? How could the bird get its skill in nest-building unless it inherited the experience of its parents and ancestors?

If the Lamarckian explanation could be accepted it would greatly simplify the causal explanation of evolution, but, much as we would like to accept this very attractive theory, we cannot at present do so, because it has never been experimentally demonstrated to be valid.

Objections to Lamarck's Theory. The most potent objection is that it is opposed to the Germ Plasm Theory, the idea that germ-cells are the product of germ cells only and never of body cells. If germ cells never come from body cells how can the germ cells profit by the experience of the body cells, for there is no known mechanism for passing along hereditary characters except the process of cell division? The second objection is that germ cells seem to be relatively immune to the influence of their surroundings. If, for example, the ovary of a white rabbit is grafted into the body of a black rabbit (after removal of the black rabbit's ovaries) and the black foster mother is then bred with a white male, the offspring are all white and show no evidence that the germ cells have been in the least affected by their foreign surroundings. Similarly, when two species of tadpoles are grafted together so as to make artificial Siamese twins, the characters of the two half individuals remain quite distinct and unchanged. Apparently, then, tissues cannot affect one another to the extent that Lamarck's theory implies, and this is especially true of germ cells for they are relatively insulated from the body tissues.

Numerous experiments have been reported from time to time attempting to prove the inheritance of acquired characters, but invariably these have been proven inadequate. At the present time there is not a single piece of valid evidence favoring Lamarck's theory.

Yet though it is true that no cases of the inheritance of the effects of somatic modifications have been demonstrated in the few generations to which these experiments must be limited, it may be that such effects would be possible if time enough were allowed. But this is a mere sentimental concession and is not to be taken too seriously.

At present it must be confessed that Lamarck's theory lacks any valid evidence in its favor and is therefore unacceptable.

Darwinism

Darwin's famous theory of Natural Selection (survival of the fittest), while ostensibly designed to solve the problem of the origin of species, is now believed to be chiefly valid as an explanation of adaptation. Darwin's theory is the product of the logical juxtaposition of certain observed facts and deductions that seem to arise naturally from them.

The observed facts are: *a,* The geometrical ratio of increase. Every species of organism, even the slowest breeding, produces enough offspring at least to double the number every generation, if all survived; *b,* Every individual of a species is different from all others in a great many particulars; *c,* Individual differences are transmissible by heredity.

The deductions from these facts are: *a,* There would not be food or room enough for all the offspring arising from a geometrical ratio of increase. There must therefore be competition among those individuals that depend upon the same life necessities; *b,* There would be more likelihood of survival of those individuals whose slight differences (variations) were more favorable and would thus give them an advantage over competitors; *c,* The surviving individuals will pass on to their offspring the characters that have given them an advantage. *Thus, through a struggle for existence, there will be a survival of the fittest and a gradual improvement in adaptive structures.*

This theory, when it was first proposed, captured the scientific world by storm. It seemed so logical and inevitable that few doubts as to its validity arose. After a few decades, however, it became apparent that the theory had a number of crucial weaknesses, of which the following may be cited as the most important:

a, The minute fluctuating variations upon which Darwin depended as the basis of selection have been shown to be largely somatic modifications and, unless Lamarck's theory holds, these are not hereditary and could therefore have no value in racial evolution.

b, It is difficult to believe that the first minute steps in the direction of a complex adaptive organ could have any survival value, and therefore they could not be helped along by natural selection.

c, There are about as many non-adaptive characters as adaptive ones, and the former could not be accounted for by natural selection.

d, It is objected that most fluctuating variations (individual differences) emphasized by Darwin are merely quantitative or plus-and-minus variations, and therefore could not account for the origin of new characters qualitatively different from old.

e, It is hardly likely that only the fittest survive, for there would be a chance of survival for all except the actually unfit unless the competition were very severe. The survival of the fittest may therefore be nothing more than the elimination of the unfit.

In defense of natural selection it may be said that if we substitute mutations, now known to be sufficiently numerous, for fluctuating variations many of the difficulties disappear. The five objections just given become irrelevant when we use mutations as the raw materials of selection. It is also to be borne in mind that even neutral or non-adaptive characters might easily be preserved if they happened to be part of the hereditary complex of well-favored types characterized by the possession of numerous advantageous characters. It is the *whole individual* that survives and not the separate characters. So it is possible for individuals with a considerable credit margin of adaptive characters to carry as excess baggage a number of useless or even slightly harmful characters. Of course the possession of seriously harmful characters, such as lethal characters in the fruit fly, will cause the elimination of the individual in which they occur.

There seems to be little question today but that natural selection is a genuine force for adaptive improvement. Even if nothing happens but the constant elimination of the unfit, or under keenest competition of all but the distinctly fit, this would result in advancement, for every once in a while a real improvement will be added by mutation and incorporated into the race.

It is a mistake to suppose that natural selection implies a keen struggle and a survival through brute force, for in many species coöperation, altruism of certain sorts, and self-sacrifice are elements of the utmost importance in racial success. The Nietschian philosophy is not in any true sense a logical conclusion from natural selection. He forgets that many of the kindlier qualities are as adaptive as any other, in man at least, and emphasizes only the harder, more cruel qualities. Man is man chiefly because of his gentler qualities and the course of the future human evolution will doubtless be along more altruistic lines than that of the past.

In conclusion then, we may say that at present the best explanation of adaptation, if we really must believe in an adaptive world, is natural selection based on mutations and combinations.

CHAPTER XII

MINOR THEORIES

In bringing this brief discussion of the causes of evolution to a close, it seems necessary merely to mention two theories, which may be briefly termed Isolation and Orthogenesis.

Isolation Theories. With mutations and combinations to furnish new characters and natural selection to act as an arbiter among those new types that appear as a result of these changes, it would still be difficult to understand how a parent species could split up into more or less separate varieties or species, for if all new characters were to be imparted through interbreeding to all members of the species no lines of demarkation would ever arise. It is here that Isolation comes to the aid of the other factors in making possible the establishment of distinct groups (species). As has already been said, if a widely distributed species were to be broken up in its range by barriers there would be a segregation of sections of the species from one another. This would happen if by any chance a pair or more of individuals were to be transported to an island, across a mountain range or a desert or a sea.

The isolated group would no longer be able to interbreed with the main body of the species and would go its way separately, developing its own set of mutations and not sharing in the mutations of the larger group. Also, if the environment were markedly different, there would be a different standard of survival among the new types produced, and thus there would be inevitable adaptive divergence in the evolutionary paths of the two groups until they became specifically or even generically distinct.

Not only would geographic isolation accomplish this end, but purely biological or psychological isolation might act without actual separation of individuals from the main range of the species. For example, if a mutation were to affect the reproductive systems of some members of the group, causing them to breed earlier or later than the main population; or if the reproductive organs were changed so as to make it impossible for the old and the new types to interbreed there would be an effective cutting off of genetic communication between the two, and new species would result. Again, as not uncommonly happens among higher animals, members of a newly produced type might have a strong preference in mating for individuals of their own kind, and this would have a tendency to establish pure races within the species. These and other isolative agencies would all be valuable as aids in enabling a new type to gain a foothold among the much more numerous members of the parent species. Some authors consider Isolation as an indispensable and therefore a major evolutionary factor. It may safely be accorded at least the rank of an important subsidiary factor.

Orthogenesis. The other factors previously discussed seem reasonably adequate to explain the origin of species and of adaptations, but there is another phase of evolution that none of these theories seem to touch upon. The study of fossil pedigrees, such as that of the horse, the elephant, the camel, and even more strikingly, those of cephalopod mollusks and of echinoderms, seem to show that evolution proceeds in definite, almost logical paths. In the horse family, for example, there is a steady increase in size, in complexity of the teeth, in length of neck and head, and there is a regular order in the loss of toes, beginning with the outside ones and proceeding inward toward the middle. If we can rely upon the fossil series to give us the correct order of events, we may say that evolutionary progress is definite and straight ahead in its course; in brief, it is *orthogenetic* (definitely directed). There is some controversy among evolutionists as to the interpretation of the data upon which the idea of orthogenesis is based, but even if the facts are as stated, it must still be admitted that the theory is little more than a descriptive statement as to the course followed in the evolution of certain groups. It is not a causal theory at all, for it does not explain the mechanics involved in the process. We have at present no mature theory as to why straight paths of evolution are followed. It may well be, however, that when one step is taken it prejudices the next and that each step limits the number of variational possibilities until finally fixity of type is reached. Why this should be so we do not know at present. The problem of Orthogenesis is one for future evolutionists to solve.

General Summary

The principle of evolution is adequately established by an immense array of evidences. The primary causal factors of evolutions are *variations* (due to combinations and mutations) and *heredity*. We have solved the problem of heredity in its major aspects, but the problem of the causes of mutations is only at the beginning of its solution. At present a concerted attack is being directed upon this problem. The Lamarckian Theory is at present untenable, while the Natural Selection seems the best available explanation of adaptations. Isolation seems to act as an accessory to other factors in species formation. Orthogenesis is still debatable as a fact and unsolved as a problem. The scientific study of evolution is in its infancy. At the present rate of advance in our knowledge a few more decades will see many aspects of the subject that are now veiled in mystery brought into the full light of day.

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